CORPORATION OF MADRAS.

TONDIARPET DRAINAGE

AND OTHER WORKS

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CORPORATION OF MADRAS,
SPECIAL WORKS DEPARTMENT,
MADRAS, 20*th June* 1909.

To

THE PRESIDENT,
Corporation of Madras.

SIR,

I have the honor to submit herewith a report, containing a description of my proposals for the sewerage of the Tondiarpet Division of Madras, and for other new works of city drainage which interconnect with Tondiarpet drainage.

I. The report begins with a brief description of the physical features of the district, and continues with a statement of the drainage principles adopted in the preparation of the scheme. Then follow discussions of these principles, and descriptions of the methods and appliances proposed to give them effect. The new work to be done is described in Sections VII to XI. Section XII gives detailed estimates of the cost of the works, and in the Appendix are given estimates for works which are not charged against Tondiarpet Drainage.

Works interconnected with the drainage of Tondiarpet.

II. It has been found impossible to prepare a scheme for the drainage of Tondiarpet without dealing with interconnected works which are mainly required for the drainage of other districts. These works are therefore fully considered, and their necessary designs and estimates are included in this report.

They comprise the following :—

1. *The construction of an Open Channel at the Sewage Farm.* Sanction has already been accorded for a portion of this work in G. O. 1700. M., but complete designs for a channel from end to end of the farm are now submitted for the first time.

2. *Taking up the cast iron pipes at the Sewage Farm,* and relaying them as a rising main from Rayapuram Pumping Station.

3. *The construction of a* 4 *ft.* 6 *in. diameter brick sewer* to carry all the sewage of Georgetown and Tondiarpet, from the point in Tondiarpet where the two flows will unite, to the proposed Farm Station. This sewer will replace part of the 36 inch

cast iron rising main from Rayapuram Pumping Station to the Sewage Farm, and its cost can be met from the sum of Rs. 2,20,000 sanctioned for the latter.

4. *The construction of a pumping station at the south end of the Sewage Farm,* to raise the whole of the sewage of Madras into the Open Channel.

5. *The construction of a* 36 *inch brick gravitation main* to replace 1,650 feet of the existing cast iron main, and to terminate in the suction-trough of the Farm Station.

These works, their objects, and design are fully described in Section IX ; and in the estimates their cost is separated from that of works required solely for the drainage of Tondiarpet. There are also 14 drawings devoted to them.

Many of the designs apply to all districts of Madras.

III. Much of the work done since my arrival has consisted of investigations, the results of which are applicable to the drainage of other districts of Madras ; and of the preparation of standard drawings, which, with slight modifications, will serve when other work comes to be designed.

The experimental work forming part of the investigations has been described in some detail, in order that the results obtained may be appraised at their true value by those who have to scrutinise these proposals.

The apparatus used in conducting the experiments may be seen at Napier Park and the results can be verified if desired.

Models of several of the appliances specially designed for Madras have been built at Napier Park, and a demonstration of their working will be given to any member of the Corporation who may wish to examine them. These appliances include the *Silt and Storm Water Separator* for side drain connections to sewers, *Silt-catcher* for house connections, and the *Silt-raiser* for raising silt deposited in pumping station silt pits. These devices are respectively described in paragraphs 68 to 71, 77 to 82 and 170-171.

Reasons for delay in presenting Report.

IV. On my arrival in Madras I was given an office staff of one clerk only, and at that time the Government, the Railway Companies, and the Madras Port Trust, had engaged every available draftsman of merit, and were wanting more. Under these circumstances it was very difficult to organise a staff for the preparation of the scheme, and even now only a few draftsmen have been obtained who can draw from sketches, and these have had no previous experience of drainage work. But besides such difficulties, the preparation of the scheme could proceed only intermittently. Its completion has been delayed by other work too pressing to be left ; by the report, plans, specifications and tenders for new work at Law College and Rayapuram Pumping Stations ; by the Waterworks, revision of plans, preparation of specifications and letting of eight new contracts, by time spent in superintendence of the new conduit and a criticism of the proposed distribution scheme, and by the unfortunate illness of my assistant Mr. Nowroji who was compelled to take 3 months leave, and for whom no one could be spared to act. The report has also been delayed by the design, preparation of drawings and

estimates, and construction of new sewers; time has had to be given to many urgent requests for inspection and advice on sewerage troubles of the failing systems—extensive silting and overflowing—on cases of non-drainage of slaughter-houses, paracherries and highly insanitary districts; all requiring many inspections, regional investigation and preparation of drawings, estimates, and reports such as have led to sewer cleaning and attempts to keep the old sewers working, until they can be remedied.

Finally, for the report itself, time has been required to make the essential close investigation of the present system (and that without reliable plans or information), to make numberless visits to every part of the city, to do experimental work and to devise methods and appliances to deal with the special problems encountered in the drainage of Madras. Time has also been required for the calculations and thinking out of new work affecting the whole city, for the preparation of over 60 drawings containing designs, all specialized for Madras conditions, and many of them quite novel. In addition, the making of careful estimates, the actual writing and proof correcting of the report, and the preparation of 15 plates, represent much time.

On the other hand, the Corporation are now, I believe, in possession of a full scheme of principles, methods, and actual designs, which if approved by Government, will simplify, standardize, and be a guide for all future house drainage, sewerage, and pumping station work to be done in Madras.

V. I understand that this report will be first circulated to the Corporation and will then be submitted to Government with the recommendations of the Corporation.

Detailed descriptions given for the benefit of the Commissioners.

In order to make everything as clear as possible to the Commissioners, I have given descriptions of the works proposed, and the reasons for recommending them, in greater detail than would be necessary to enable the expert advisers of Government to understand them.

While it is impossible in a single report to give sufficient information to enable a layman to criticise the engineering features of the scheme, nevertheless it may be possible to convince him that everything proposed has been carefully thought out with a view to obtaining the best possible results in economy and efficiency, and of adapting to Madras conditions the results of the experience of other cities as far as these results are applicable; and that where the conditions of Madras render special appliances desirable, such have been devised.

With the same object—to make it possible for laymen to follow the proposals—a number of plates have been prepared and are bound up with the report. They are intended to illustrate the text, but not to take the place of the drawings. To obtain an accurate understanding of the scheme, it is necessary to examine the drawings in conjunction with the report.

VI. The existing faulty sewerage systems of Madras have been dealt with at considerable length in my Quarterly Reports.

Urgency of remedying existing defective drainage

In these Reports I have pointed out that the underground system has completely broken down in places—for example in Periamet where a large proportion of the sewage has been turned into the Cooum. In every district the

existing sewers are very inefficient, and, in their present state, must be a menace to the health of the inhabitants.

The causes of failure have also been pointed out in my quarterly reports, and methods of remedy have been indicated.

The heroic way would be to remodel the entire existing drainage on the lines set out in this report, and such a course would undoubtedly give satisfactory results. But I have reason to hope that it may be possible to get good results from the existing sewers without such drastic treatment. It will nevertheless be necessary to carry out further investigations to determine what will be the effect of remedial measures such as the exclusion of silt and storm water by the means and appliances described in this report, and by alterations to the defective pumping stations for which plans are now in the course of preparation in my department.

If silt be excluded from the Periamet, Mylapore and Triplicane sewers, an improvement will take place which may be of great importance ; and which, combined with exceptionally good and frequent flushing, may save much relaying. Experiments made at Napier Park with lengths of 6 inch and 9 inch pipes laid at gradients of 1 in 330 and 1 in 500 respectively—the gradients of the defective sewers—shewed that with moderate flows, silt would be removed *in time.* In the Madras sewers, the time available is at present utterly insufficient. Before the first quantity can be carried off, additional silt is added, and accumulation takes place even though the sewer may have a free outfall. The use of silt-catchers, the insertion of separators, regular frequent and automatic flushing, will however very greatly improve things in all the badly sewered districts of Madras.

With silt and screening pits added, and with improved pump deliveries, the existing pumping stations can be made to do far more satisfactory work than hitherto. On the other hand, no system of working can keep badly jointed, badly connected and collapsing sewers in good order ; and such must of course be relaid, and the bad gradients may entail the deepening of some of the existing pumping station wells and main sewers.

This work is, in my opinion, more urgent than the drainage of Tondiarpet, and the questions of where first to spend the funds which can be devoted to drainage, and of the wisest division of those funds, are I consider of immediate importance, and require determining as soon as possible.

Proposed order of carrying out works.

VII. The work to be done, in what now appears to be its order of urgency, is as follows :—

1. To carry out and complete the new work for Rayapuram and Law College Pumping Stations, *viz.*, erect pumping plant at both stations, let contracts for the new building for the Law College Pumping Station, and for the silt-pits, screening chambers and suction wells, at both stations.
2. To build the Open Channel at the Sewage Farm.
3. To temporarily connect the existing 36 inch pumping main with the Open Channel.

4. To take steps to remedy the serious silting up of the sewers, and overflow of sewage on to the streets in Periamet, Triplicane and Mylapore. To remove all broken and collapsing sewers, including the cracked concrete pipes in Mylapore. To provide adequate ventilation and efficient flushing for all sewers. Until this is done, all Georgetown sewage should be pumped to the farm through the existing 24 inch main.
5. To provide all the existing pumping stations with improved deliveries, Venturi meters, silt and screening pits.
   I may mention that the plans and surveys for new deliveries and Venturi meters are already nearly finished, and standard plans for silt and screen pits are included in this report.
6. To remedy—as shewn in the report—all existing house and side drain connections that at present allow silt, rainwater, and refuse to enter the old sewers.
7. To construct in the existing sewerage areas any new main sewers that investigation shews to be necessary, and complete remedial measures involving re-laying of bad sewers. Also to complete the drainage of Triplicane and other areas only partly sewered.
8. (*a*) To lay the 36 inch pumping main from Rayapuram Station to the proposed Bell-mouth Chamber in South Tondiarpet.
   (*b*) To construct the 4′—6″ sewer from the above Chamber to the proposed large Farm Pumping Station.
   (*c*) To build the Farm Station, partly engine it, and turn Georgetown and Tondiarpet sewage into its suction-trough.
9. To lay the 36 inch brick gravitation main from the valve chamber to the Farm Station, cut the 33 inch cast iron main and turn its sewage into the new brick main, thereby taking 17 feet off the head pumped against at all the five stations which deliver into the cast iron main.
10. To carry out the drainage of South Tondiarpet as already fully designed.
11. To take such steps as are found necessary to increase the pumping capacity of the plant at Mylapore, Ice House Road, Napier Park, Langs Gardens, and DeMellow's Road Pumping Stations ; and also—the existing main being too small—to prepare and carry out a scheme for conveying to the Sewage Farm the greatly increased quantity of sewage which will be pumped from these stations when the new water-supply has been introduced, and the improvements and remedies to the pumping plants and sewers have been completed.

The above is an outline of the work which should be done and the order in which it should be carried out as far as can be judged at present.

New developments may, however, alter the order of urgency, and it may be advisable to carry out at an early date works which are not mentioned here at all : for instance, the drainage system of Georgetown may very well become

such a nuisance as to make it advisable to lay down a complete system of underground sewers, and it is certain that some of the main sewers of Georgetown will have to be taken up and replaced by larger sewers before long.

Side drains.

VIII. I have assumed that the Corporation have decided to adopt underground sewers wherever new work is put in, but in order that there may be no doubt as to my own views, I take this opportunity to state that I am strongly in favour of underground sewers, combined with the water carriage removal of excreta. Comparison may possibly be made between the merits of side drains and the benefits of underground sewers. But the underground sewers of Madras must be excluded from such comparison, on account of their very serious defects, which would never be found in a well designed sewerage system. Side drains—they were complained of even in Roman days—were abandoned in most western cities nearly a hundred years ago, and they are now rapidly going out of use in India for many good reasons.

Sewage should never be exposed, for it is always giving off a complex mixture of gases known to be most inimical to human life. This gas should be confined to its proper place, and liberated well over head. At present the most familiar smell in the denser parts of this city is that of gas rising from putrifying sewage. The gas itself has not been found to contain normally germs in greater number than ordinary air, but it acts poisonously and insidiously, lowers vitality, and renders those who breathe it unhealthy, and unable to resist disease.

House flies may be observed any day in Madras to settle on the wetted portion of side drains, and to fly directly thence and alight on passers by, on children eyes, on oppers and other food on the stalls of the bazaars. There may be washings and urine in that sewage, from a victim of enteric, tuberculosis, or cholera, and many diseases are known to be conveyed by flies.

Nearly all exposed sewage in Madras may be seen to be the feeding or breeding place of countless mosquitoes ; these insects are not only a pest, but are well known to be the great source of malaria, and for this reason alone side drains should be abolished. The great danger of providing mosquitoes with attractive places near dwellings, has but recently been pointed out forcibly, in a lucid pamphlet issued by one of the Commissioners of this city. Every time it rains, quantities of sand and road metal get washed into side drains, which are also the receptacles for much garbage and rubbish that should go direct to the incinerators. All this silt and rubbish has to be taken out by hand labour ; it is deposited on the roadside, and the dried silt and fouled rubbish are trodden and blown about, disseminating a foul dust and any germs it may contain. It is almost impossible to avoid frequent blockage of the side drains, for it may take place only a few minutes after cleaning, and in consequence, a side drain normally contains pools of more or less stagnant sewage.

No one can deny the unsightliness of side drains, and to pass through Georgetown without inhaling sewer gas is an impossibility. Side drains commonly reduce the useful width of a street by several feet, often by 5 or 6 feet ; a serious matter in busy parts that are yearly becoming more thronged. The proper function of side drains is the conveyance of rainwater, and for this purpose, they should be arranged as described in the body of the report.

The importance of educating people to object to the sight and smell of sewage is great, for it affects their morals and health. Side drains encourage insanitation ; that is, they make for dirt, smell, and a high death-rate. All cities that have adopted *good* underground drainage, have shewn a decrease in death rate ; the benefit has often been very immediate and marked. A grave fault resulting from open drains is the necessity for hand removal of excreta, which—as carried out in Madras—is a filthy and degrading occupation employing a large amount of child and woman labour. Compared with the cleanly flushout latrine and the water closet, it is indeed a barbarism.

In conclusion, I should like to mention that my Assistant—Mr. E. P. Richards—has devoted himself whole heartedly to working out the details of the scheme. With two or three exceptions, the draftsmen are quite incompetent to prepare drawings from sketches, and to Mr. Richards is due the credit for any merits which the drawings may possess. For the last six months he has utilized all his spare time and holidays to hasten the completion of the work.

I have the honour to be,

Sir,

Your most obedient servant,

J. W. MADELEY, M.A., M. Inst. C.E.,

Special Engineer, Corporation of Madras.

SECTION I.

Topography and Physiography.

Boundaries of Tondiarpet Division (Drawing No. 1.)

1. Tondiarpet is the most Northern division of Madras, it is of a rectangular shape, and measures about 3 miles from North to South, by an average of about $1\frac{3}{4}$ miles from East to West. A reference to Drawing No. 1 will show the position of Tondiarpet and its relation to the areas of Madras which have already been partially drained. The drawing also shows the positions of the existing pumping stations, and the mains which now convey the sewage from the stations to the sewage farm.

The eastern boundary is formed by the sea and extends northwards for nearly three miles, from the northern arm of the harbour to the North boundary of the City of Madras, which is also the North boundary of Tondiarpet.

The western boundary coincides with the boundary of the City of Madras as far as Erukkanjeri Road, which it follows to the Buckingham Canal. The Canal then forms the limit until the southern boundary—Old Jail Street—is reached.

Strip lying on west side of the railway is marshy.

2. The whole strip of Tondiarpet lying *West* of the railway is marshy and low-lying. It is uninhabited now, and is likely to remain so for at least twenty or thirty years to come. Opposite to Korukupet the marsh is being raised artificially by deposits of refuse, but these will be unhealthy to build on for a long while. The low-lying character of this long marshy area will be understood, when it is remembered that the railway, which runs due North along the edge of the marsh for over 2 miles, rests upon an embankment of practically the same height throughout.

Strip south of railway.

The whole strip of Tondiarpet lying *South* of the railway will be drained to Rayapuram Pumping Station.

Tondiarpet of this report

3. Therefore—dismissing the outside strips to the west and south—it is that portion of Tondiarpet enclosed by the railway, the sea and the north boundary of the Municipality which has to be dealt with. In the report "Tondiarpet" will mean this latter area, which for sewerage purposes, may be considered to be Tondiarpet proper, and which, as it stands to-day, is a largely drainable and inhabitable area of Madras.

Encroachment of western marsh eastwards beyond the railway.

4. The term "*largely* drainable" is used above, because the western marsh extends beyond the railway, and forms a long narrow piece of the area referred to as Tondiarpet proper. This narrow strip is, at present, both undrainable and uninhabitable. The railway running north is the boundary of Tondiarpet proper, but not of the marsh, which extends eastwards for an average distance of 200 yards beyond the railway and for a length of over $1\frac{3}{4}$ miles. A glance at the contoured map (Drawing No. 2) will show clearly the edge of the marsh, its surface being only about 5 or 6 feet above mean sea-level, and its boundary coinciding closely with the 26·60 contour.

Levels and Contours (Drawings 2 & 3)

5. Before commencing actual design, it was essential to take levels over the whole of Tondiarpet. When this had been done contoured plans were constructed from the results. These are now embodied in drawings Nos. 2 & 3. By their aid, the advantages of the physical features of the district have been utilised in selecting the best positions for pumping stations, the best routes for main sewers, and the most economical and efficient lay out of the sewer network. The planning of the scheme is fully dealt with in Section X.

On the contoured plans the darkest colour signifies the highest ground and the lightest colour the lowest ground. All levels given, refer to a datum plane assumed at 20 feet *below* mean sea-level : thus "26·60" means 26·60 feet above that plane, or 6·60 feet above mean sea-level.

Physiography.

6. The physiography of Tondiarpet is simple. The sub-soil is sand, sandy, loam, and clayey loam. The whole area of Tondiarpet is very flat, there being a difference of only about 12 feet between the highest and lowest points.

On referring to the contoured Plans and to Plate No. 1, a wide flat roll of higher ground will be seen commencing near the middle of the north boundary ; this major roll runs down through the middle of Tondiarpet to within three-quarters of a mile of the railway, at which point it spreads out irregularly, and divides into two minor rolls, both of which run southward to the southern boundary of Tondiarpet.

The axis of the eastern of these two lesser rolls is along the line of Mannarsawmi Kovil Street ; the western minor roll lies a few hundred yards west of Monegar Choultry Road. A line diagram along the top of the rolls is, therefore, something like the letter "Y" inverted ; the two small arms in the south being shorter than the long stem in the north. On plate No. 1, it will be seen clearly that these flat rolls cause the west side of Tondiarpet to slope westwards to the marsh, and the east side to slope eastwards to the sea ; while between the minor rolls in the south, there is a basin-like depression, which gets wider as it meets the railway. The old existing "scoop drain" runs down this hollow.

To summarize the physiography—three-fourths of Tondiarpet, from the North southwards, has a long central roll, from which the ground slopes East and West : The most southern part of Tondiarpet has two minor rolls, giving a slope to the West, a shallow central valley and then a slope to the East.

SECTION II.

Principles adopted in Design.

7. In G.O., No. 1671 M., dated 17th September 1906, it is laid down that detailed plans and estimates for the drainage of the Tondiarpet Section of Madras should be prepared in consultation with the Sanitary Engineer to Government on the lines suggested by that officer. General.

Unfortunately, Mr. Hutton, the officer referred to, was away on leave during the whole of the time that the scheme was under preparation, and, in consequence, it has been impossible to seek his advice, or to discuss modifications of his proposals. As, however, the appointment of Special Engineer was made more than a year after the date of the G. O. in question, and as one of the objects of the appointment was to carry out the drainage works, the recommendations mentioned have not been accepted without going into them carefully, and modifying them where it appeared desirable. The most important modification made, is the alteration of the limiting gradients of sewers.

8. For purposes of comparison, the following statement is given of the principles laid down in G. O. 1671 M. and the extent to which they have been adopted or modified.

Principles proposed by the Sanitary Engineer.	Principles adopted in the scheme forming the Subject of this Report.	
1. That the sizes of sewers in all cases should be fixed to carry off in six hours, when flowing half full, half the whole daily quantity of sewage from the section.	1. The sizes of sewers in all cases have been fixed to carry off in six hours, half the whole daily quantity of sewage of the anticipated ultimate population of the areas drained by them, plus an allowance for rainfall equal to one-third of the maximum flow. The pipe sewers will be half full and the brick sewers three quarters full, when carrying this flow.	Modifications of G.O. 1671, M.
2. That the rate of sewage flow is based on the supply of 25 gallons per head per day of population in the year when the system is first brought into operation.	2. The mean rate of flow for the sewers is taken as 25 gallons per head per day of the anticipated ultimate population. The allowance for rainfall referred to in the last paragraph is made in accordance with the rule laid down by the Chief Engineer to Government in G.O., No. 1488 M., dated 22nd July 1907. The question of the maximum, mean, and minimum flows, is dealt with in Section No. III.	Dry weather sewage.

3. That all sewers be laid at self-cleansing gradients and that the minimum gradients be :—

For	4″	pipes	1 in 52
„	6″	„	1 in 100
„	9″	„	1 in 190
„	12″	„	1 in 295
„	15″	„	1 in 415
„	18″	„	1 in 540

3. The sewers have been laid out at gradients which will give self-cleansing velocities : the minimum gradients are :—

4″	pipes	1 in 40
6″	„	1 in 135
9″	„	1 in 230
12″	„	1 in 340
15″	„	1 in 460
18″	„	1 in 580
21″	„	1 in 720
24″	„	1 in 860

The question of gradients is of very great importance and has been most carefully considered. It is dealt with at some length in Section III.

4. For sewers above 18 ins. in diameter, conduits of the new oval section to be used.

4. In some cases 24 inch cast iron pipes are utilised as sewers. The 4½ feet main sewer to the sewage farm has been designed of circular section, after carefully balancing the advantages of this section as compared with the oval section.

5. That manholes more than 300 feet apart should be provided with surface boxes for easy entrance.

5. All manholes will be provided with cast iron covers. There will never be more than 300 feet between adjacent manholes.

6. That ventilating shafts be provided every 600 feet apart and that intermediate air inlets be provided.

6. It is impossible to apply an exact rule to sewer ventilation : 600 ft. apart may be taken as a fair standard on large sewers. This question is dealt with in section VII, paragraphs 99 to 107.

7. That at main crossings of roads Webb's sewer extractors and lamp for lighting purposes combined be used additional to No. 6.

7. Where the conditions render them necessary, special measures will be taken to secure adequate ventilation.

8. That none but best English stoneware pipes be used.

8. No modification of Sanitary Engineer's proposal.

9. That the jointing be done with tarred yarn and neat cement.	9. A mixture of cement and sand will be used. The use of neat cement has frequently been known to cause fracture of the sockets owing to quite normal expansion of the cement. A gasket of tarred yarn will be employed.
10. That in places where the stoneware pipe sewers have to be laid in a sub-soil charged with water, such pipes should have special joints and be laid on a bed of cement concrete, 6″ thick.	10. Stoneware pipes with Hassall's patent double lined joints have been provided in the estimates for places where water is encountered in considerable quantities. Concrete will be used where the depth of the sewer and the nature of the ground require it.
11. That the number of pumping stations be such that conditions Nos. 1 to 3 can be fulfilled.	11. The number of pumping stations will be such that the modified conditions, as stated above, can be fulfilled.
12. That as the present cast iron main is too small to take the Tondiarpet sewage, a separate main to the sewage farm be provided.	12. A circular sewer 4 feet 6 inches in diameter is provided to take the combined Georgetown and Tondiarpet Sewage.
13. That the size of the rising main be such that it will carry half the whole quantity of sewage in 6 hours with a velocity of not less than 2 feet per second calculated by Kutter's formulæ.	13. Fortunately, no long rising mains, such as the Sanitary Engineer had in mind, will be required. The velocity through the discharge pipes will be not less than 2 feet per second, under the conditions named.
14. That the engine power be laid down suitable to pump sewage for 15 years after the opening of the works when it can be replaced by more powerful plant.	14. The engine power proposed is suitable to pump the maximum sewage flow (plus an allowance for rain water,) of the population of 1901, plus 35 per cent. for increase up to the end of the period during which the pumps will be in service.

Additional Principles.

15. All silt will be excluded from the sewers, as far as possible, and special devices have been designed and experimented with to effect this purpose.

16. Special arrangements are provided to exclude as much storm water as possible.

17. Arrangements are provided for flushing the heads of all sewers, and such special sections as require it.

18. Waste water from street fountains and washing places will be utilised for flushing both latrines and sewers.

19. The pumps have been arranged to work with low lift, against a constant head.

20. All sewage arriving at the Stations, will be deprived of silt and screened before it reaches the pumps.

A discussion of the most important of the above principles—so far as they admit of discussion—will be found in the sections immediately following.

SECTION III.

Sewer Gradients—Velocities—Silt Transportation.

Outline of discussion in following paragraphs.

9. In order that the discussion, which forms the subject matter of this section, may be readily understood, the following brief summary of the argument is given :—

It is of great importance in Madras that the gradients of many of the sewers, more especially of the main sewers, should be the flattest that are consistent with efficiency. In the Tondiarpet scheme all gradients are limited by the velocities which must be maintained in the sewers to keep them self-cleansing. The least allowable velocity, with the ordinary minimum flow, is fixed at $1\frac{1}{2}$ feet per second, which, under the conditions obtaining in Madras, means a velocity of about $2\frac{2}{3}$ feet per second in the pipes when flowing half full.

The gradients chosen for Tondiarpet will insure that velocity. A comparative table (paragraph 16) shows the gradients adopted in good practice.

In order to make sure that the gradients are sufficiently steep, a series of experiments has been carried out to determine the velocity of sewage, and its silt carrying capacity, in pipe sewers laid at the flattest gradients proposed. The results are tabulated, and velocity and flow curves have been plotted.

These investigations prove that the gradients proposed are suitable.

Principles considered in detail.

Considerations affecting gradients.

10. The question of the gradients at which the sewers should be laid, is of vital importance in all sewerage schemes, and especially in schemes for cities like Madras, where the surface is so flat that less than ordinary assistance is to be obtained from the natural slope of the ground.

Efficiency dictates gradients sufficiently steep to ensure that the system will perform its proper function—the removal of sewage—with a minimum amount of attention.

Economy requires that gradients shall be as flat as possible, in order that the cost of laying sewers at great depths, and the multiplication of pumping stations, may both be reduced to a minimum.

Importance of adopting flattest gradients which can be used with safety.

11. The great importance of choosing, for the main sewers, the flattest gradients which can be used with safety is well illustrated in Tondiarpet.

With the gradients now proposed, *three* pumping stations only will be required to drain South Tondiarpet. The positions of these pumping stations and the areas which they will efficiently drain are shown on Plate 10.

If the gradients adopted were those proposed in G. O., No. 1671, M. (referred to hereinafter as "G. O. Gradients") *seven* pumping stations would be necessary to drain the same areas, assuming that the depths of the pump wells are the same in both cases. The positions of these stations, and the areas which would drain to them are shown on Plate 2.

The initial cost of seven very small stations, in respect of land, buildings, engines, pumps, silt pits, screening chambers—in fact everything—would be much greater than three stations of moderate size.

The cost of upkeep and of running the plant would also be very much greater for seven pumping stations than for three, in respect of everything, including wages, fuel, oil, repairs, renewals and depreciation.

In order to decide exactly what would be required, a good deal of time was spent in working out the system of sewers and pumping stations assuming that G.O. gradients would be used. The rough plans are in the Special Works Department. They have not been included amongst the drawings accompanying this Report, but can soon be finished off, if required, or if it should be decided that G.O. gradients must be employed.

12. To summarize : it is of the utmost importance in Madras that the sewers should be laid at the flattest gradients which are consistent with efficiency. It now remains to justify the belief that the gradients proposed will be efficient.

Gradients limited by velocities which may be allowed.

13. The gradient or slope of a sewer should be so determined that, under all the variations of flow, for which the sewer is designed, the velocity of the sewage shall lie between two limits :—

(*a*) *An upper limit of velocity*, beyond which there is danger of attrition of the sewer wall, and risk of the larger floating solids being left stranded owing to insufficient depth of sewage. In the sewage of Madras there is a considerable quantity of grit containing a large proportion of grains of quartz—the hardest of common minerals. To insure that these quartz grains shall not erode the sewers, it is necessary to restrict the maximum allowable velocity to about 5 feet per second. This limit is not likely to be reached in Madras, except in the case of short branch sewers for which suitable arrangements have been provided.

(*b*) *A lower limit of velocity*, below which, sand, silt, and other materials heavier than water, cease to be carried in suspension, and are deposited in the sewer. This velocity determines the flattest gradients which are permissible.

In the case of Tondiarpet the upper limit requires no further attention. The lower limit on account of its great importance will be considered in some detail.

Velocities required to keep solids in suspension.

14. The following table will give an idea of the lowest mean velocities which are necessary to keep the heavier solids moving in a fairly smooth channel

Material.	Mean Velocity in feet per second to keep it moving.
Fine clay	0·4
Sand size of aniseed	0·5
Gravel size of peas	0·8
Gravel size of beans	1·6
Shingle about 1 inch in diameter ...	3·3
Angular stones 1½ inches diameter ...	4·5

Minimum velocity 1½ feet per second.

15. The figures in this table were experimentally determined by Du Buat. They show that a velocity of 1½ feet per second should be sufficient to transport any solid matter which may be legitimately introduced into the sewer : and experience with actual sewerage systems confirms this deduction from experiment.

It is on the basis that a velocity of at least $1\frac{1}{2}$ feet per second shall be maintained with the ordinary minimum flow, that the proposed flattest gradients have been fixed.

Maximum velocity with a given minimum velocity varies with the conditions.

16. In previous discussions on the gradients of sewers for Madras, reference seems to have been made only to the velocity required when the sewer is carrying the *maximum* quantity of sewage for which it is designed. But it is the *minimum* flow which determines the flattest gradients which may be employed, because it is with the minimum flow that the velocity is least, and the depth of sewage least, and these are the conditions most favourable for the deposit of materials carried in suspension.

Now the relation between the minimum and maximum flow varies in different cities, because it depends largely on the amount of rainfall which is admitted into the sewers.

It is obvious that, if a sewer is designed to take all the rain-water of its drainage area which may fall during the monsoon, then the maximum flow will be very much greater than the minimum—about 200 times as great—but the actual ratio will depend on density of population, permeability and steepness of ground, etc.

Even in England—where the rainfall is very much more evenly distributed than in Madras—the amount of rainfall admitted has a great effect on the relation of the maximum to minimum flow, and therefore on the gradients and sizes of the sewers.

To illustrate this point the table below has been prepared. It shows limiting gradients commonly adopted in good English practice (and the resulting velocities when flowing half full) for sewers designed to deal with different quantities of rain-water.

Diameter of sewer in inches.	Separate system admitting only sewage and rainwater from yards and roofs.	Combined System.	
		To carry off 6 times dry weather flow.	To carry off 12 times dry weather flow.
6	1 in 150	1 in 135	1 in 87
9	1 in 335	1 in 230	1 in 150
12	1 in 490	1 in 340	1 in 222
15	1 in 660	1 in 460	1 in 295
18	1 in 840	1 in 580	1 in 375
21	1 in 1,000	1 in 720	1 in 460
24	1 in 1,250	1 in 860	1 in 550
Velocity in feet per second when running half full.	$2\frac{1}{4}$	$2\frac{2}{3}$	$3\frac{1}{3}$

From this table it will be seen how the limiting gradients and maximum velocities vary according to circumstances. In the scheme proposed in this report

the amount of rain-water admitted will approximate to the first of the three sets of conditions given above. But there are reasons, such as the presence of silt in the sewage and the absence of useful flushes from house connections, which render steeper gradients advisable in Madras.

Experimental determination of sewage flow in Madras.

17. As it is the *maximum* flow which has always been referred to in previous reports, it will be convenient to continue to do so, and to find out what the velocity will be under the conditions of maximum flow in Madras sewers when the minimum rate of flow is $1\frac{1}{2}$ feet per second.

Enquiries having elicited the information that no measurements of the sewage flow throughout the day were available, it was decided to ascertain the quantity which reached the Pumping Station in Lang's Gardens.

This station was chosen because it is the only one furnished with piston pumps which are able to cope with the maximum dry weather flow.

By means of counters attached to the pumps, the number of strokes was obtained every half hour. This gave a measure of the quantity pumped. The sewage level in the pump wells was kept as constant as possible, and was noted at the same time that the number of strokes was recorded: by this means was determined the excess or deficiency of the quantity pumped, compared with the quantity flowing into the well.

The experiments were continued for several days and the results are given in Plate No. 3.

In this way the ratio of the mean flow to the maximum, and to the ordinary minimum, was found to be as 1 is to $\frac{1}{2}$ and as 1 is to $1\frac{2}{3}$.

By the *ordinary minimum* is meant the quantity which should be treated as the minimum for sewage design. As will be seen from Plate No. 3, the *absolute minimum* occurs between midnight and 2 A.M., but during this time the liquid consists of practically clear water and does not affect the case.

These experiments show that the maximum dry weather flow may be taken with safety to be twice the average, and the ordinary minimum to be one half the average, and this gives a relation of maximum to minimum dry weather flow, of 1 to $\frac{1}{4}$. This ratio has been adopted as a basis in the calculations which follow.

Velocity should be $2\frac{2}{3}$ feet per second when flowing half full.

18. But the sewers of Tondiarpet are designed to take the maximum dry weather flow *plus an allowance of one-third of that quantity for rain-water which cannot be excluded.* Therefore the ratio between the minimum and maximum flows becomes as one quarter is to one and a third, (as $\frac{1}{4}$ is to $1\frac{1}{3}$) or as $\frac{3}{16}$ is to 1.

As all except the largest Tondiarpet sewers are designed to take the maximum flow when running half full, the ordinary minimum flow will amount to $\frac{3}{32}$ say $\frac{1}{11}$th of the carrying capacity of the sewer running full.

Now $\frac{1}{11}$th is carried when the depth of flow in the sewer is 0·20 of the diameter and when the velocity is 0·58 of the velocity of the same sewer flowing full; so that the gradients of the sewers should be such, that their maximum velocity when flowing half full is at least $\frac{1\cdot5}{0\cdot58} = 2\cdot59$, or say $2\frac{2}{3}$ feet per second.

It will be noticed that two approximations have been made, both on the safe side, as regards efficiency, so that $2\frac{2}{3}$ feet per second with the maximum flow, will insure a velocity of rather *more* than $1\frac{1}{2}$ feet per second with the minimum flow.

The velocities in the flattest designed sewers will be :—

With minimum dry weather flow	...	1·68 ft. per second.
With mean " " "	...	2·03 " " "
With maximum " " "	...	2·43 " " "
With maximum flow for which sewers are designed	...	2·66 " " "
With flow ¾ depth of pipe		3·03 " " "

Gradients must insure a velocity of 2½ feet per second in sewers flowing half full.

The gradients required to produce these velocities have been obtained from the tables prepared by Santo Crimp & Bruges. These tables are based on the results of experiments conducted on sewers, and are believed to be the best available : they have been used in England by most of the leading civil Engineers and found reliable ; and they agree closely with the Napier Park Pipe experiments described below.

Their exceptional value lies in the fact that they have been constructed as the result of repeated experiments, conducted under conditions of ordinary working, on sewers of the sizes proposed for Tondiarpet. They are preferred to tables based on Kutter's formula, because this formula was derived from experiments carried out in channels, and is known to give velocities which are too low for pipes up to 18 inches in diameter.

Comparison of gradients.

20. For purposes of comparison the following table has been prepared, in which are set out the flattest gradients for sewers :—

1. As laid in Madras by the late " New Drainage Works."
2. As now laid in Bombay.
3. As laid in Stockport (England),
4. As recommended by Baldwin Latham in his book on "Sanitary Engineering" which is the outcome of a very extensive experience of sewerage works all over the world.
5. As proposed in G.O., 1671. M., *i.e.*, the " G.O. Gradients."
6. As proposed in this Report.

It will be noted that, with the exception of the G.O. Gradients, the gradients now recommended are the steepest, whilst those adopted in Madras by the late " New Drainage Works " are by far the flattest.

Diameter of sewer in inches.	FLATTEST GRADIENTS FOR SEWERS.					
	As adopted in			As recommended by Baldwin Latham.	As proposed	
	Madras by late " New Drainage Works." (1)	Bombay. (2)	Stockport (England). (3)	(4)	G. O. Gradients. (5)	IN THIS REPORT. (6)
6	1 in 330	1 in 150	1 in 135	1 in 137	1 in 100	1 in 135
9	500	265	300	206	190	230
12	600	385	400	386	295	340
15	1000	...	500	482	415	460
18	1000	660	650	579	540	580
21	...	...	...	...	...	720
24	...	980	...	772	...	860

The gradients given above in the last column are the flattest proposed for the pipes of the sizes given in the first column, but, *wherever possible, steeper gradients will be employed in Madras and Tondiarpet*, for, although the gradients proposed are efficient, steeper gradients giving velocities of from 3 to 5 feet per second are more desirable.

To illustrate the extent to which steeper gradients are proposed for Tondiarpet in this scheme, it may be mentioned that out of a length of 101,500 feet of 6 inch pipes 46·3 per cent. are to be laid at gradients of from 1 in 100 to 1 in 40, the latter gradient is as steep as it is advisable to lay these pipes.

Experiments on the flow of sewage in 6 inch and 9 inch pipes laid at the flattest gradients proposed.

21. So important is the question of gradients, that it was considered advisable to test the flow in actual experimental pipe lines laid at the flattest gradients proposed, and to ascertain the transporting power of water in respect of the actual silt which finds its way into the sewers of Madras.

These experiments have been carried out at Napier Park. Two lines of pipes, one 6 inches and the other 9 inches in diameter were laid parallel and straight and the length of each was the same—110 feet from inlet to outlet. Vertical junctions were laid at short intervals so that the interior of the pipes might be inspected closely. The 6 inch pipes were laid at a gradient of 1 in 135. The 9 inch pipes were laid at a gradient of 1 in 230.

The joints were made with yarn and clay, and ordinary sight rails were used ; the boning rods were held on the top of the pipes—as appears to have been the usual custom in Madras—so that there was a certain amount of irregularity along the invert. This was done purposely in order that the laying should be no better than in the present sewers of Madras, but this method of laying is strongly condemned. Plate 4 shows the arrangements for the experiment.

The liquid used was dirty water resembling sewage ; it was pumped into a circular feed tank, whence it gravitated to the pipes, passing first through a valve by which the quantity flowing was regulated, and then into a rectangular trough provided with a weir, by which the quantity was measured. The outlet was connected with a pit from which the liquid was pumped back to the feed tank. In order to maintain a constant head, the overflow of the feed tank was kept just running.

The accuracy of the weir formula was checked by taking a positive measurement of the liquid flowing, as determined by the rate at which the tank was emptied. A reference to detail No. 3 of the table will show that the agreement is remarkably close between the rate of flow as thus determined, and the rate as calculated by the weir formula.

A summary of the experiments is given in the following table. Each result is the average of a number of measurements. To record the individual observations, more space than is available would be required.

22. Table showing summary of results of experiments on flow of sewage in 6 inch and 9 inch pipes laid at the flattest gradients proposed for Tondiarpet.

	6 inch pipes.				9 inch pipes.			
	Minimum flow.	Mean flow.	Maximum flow.	Half full.	Minimum flow.	Mean flow.	Maximum flow.	Half full.
1. Head above weir, 1 ft. long, in inches..	0·75	1·20	2·25	2·75	1·28	2·02	3·98	4·37
2. Flow from weir formula in gallons per minute	18·80	37·6	98·0	130·0	41·5	83·1	221·5	25·3
3. Flow, as measured by fall in level in circular tank, in gallons per minute...	18·90				42·7			
4. Mean velocity in pipes as measured by lime solution in feet per second ...	1·73	2·25	3·00	3 16	1·72	2·11	2·82	3·06
5. Velocity from Tables of Santo Crimp & Bruges for same quantity and gradient, in feet per second.	1·68	2 03	2·66	2·66	1·68	2·03	2·66	2·66
6. Velocity of floats in feet per second. ...	2·08	2·56	3·44	3·67	2·12	2·50	3·38	3·66
7. Depth of stream in inches	1·20	1·68	2·76	3·00	1·80	2·61		
8. Width of stream surface in inches ...	$4\frac{3}{4}$		$5\frac{13}{16}$	$5\frac{15}{16}$	$7\frac{3}{16}$	$8\frac{1}{4}$		
9. Length of pipe, experimented on, in feet	110	110	110	110	110	110	110	110
10. Gradient of pipes	1 in 135	1 in 135	1 in 135	1 in 135	1 in 230	1 in 230	1 in 230	1 in 230
11. Head of entry in inches				2 6	0·23			

Notes.—In the float experiments, teak shavings were used rolled into cylinders about an inch in diameter and an inch in depth. They floated practically wholly immersed. The mean velocity was determined by introducing a solution of lime at the inlet end, and noting how long it took to reach the outlet, as measured by the average of the time taken before the lime first began to appear, and until the liquid became clear again. It was assumed that the slightly lower velocity at the inlet into the pipe and the slightly higher velocity at the outlet neutralized one another, so that the mean velocity was obtained by dividing the length of the pipe by the time taken to traverse it.

Experiments on the velocity between points unaffected by the end effects, proved that this assumption was correct within the limits of error of the observations.

Example of detailed observations of velocity.

23. The following figures are typical of an observation of velocities, and show how consistent are the times obtained. They also show that the velocity of the floats, as would be expected, is approximately the maximum velocity of any part of the liquid, for they came through more quickly than the first part of the lime solution.

6 inch Pipe.

Gradient, 1 in 135.

Head over measuring weir 1 foot wide, $\frac{3}{4}$ inch.

Corresponding calculated flow, 18·8 gallons per minute.

Length of pipe, 110 feet.

Time taken to traverse pipe.—

	Began to appear at outlet.	Ceased to appear.	Mean time.
Lime Solution.	55 seconds.	72 seconds.	63·5 seconds.
	54 ,,	72 ,,	63·0 ,,
	54 ,,	73 ,,	63·5 ,,
	55 ,,	73 ,,	64·0 ,,
		Mean.	63·5 seconds.

Mean Velocity $= \frac{110}{63 \cdot 5} = 1 \cdot 73$ feet per second.

Float Experiment.

Time taken by floats to traverse pipe.

52 seconds.
53 ,,
53 ,,
53 ,,

Mean 53 seconds. Mean velocity $= \frac{110}{53} = 2 \cdot 08$ feet per second.

Depth of stream in inches $1\frac{5}{32}$, $1\frac{3}{16}$, $1\frac{1}{8}$ } Average $1\frac{5}{32}$.

Width of Stream in inches $4\frac{3}{4}$, $4\frac{3}{4}$, $4\frac{3}{4}$ } Average $4\frac{3}{4}$.

Diameter of pipes in inches $5\frac{7}{8}$, $5\frac{7}{8}$, $5\frac{7}{8}$ } Average $5\frac{7}{8}$.

24. These experiments have been described in some detail in order that the results may be of use to others. If the conditions were not fully specified, it would be difficult to appraise their value, and to decide in what degree they are applicable to other cases. The apparatus used is still at Napier Park, so that the experiments may be repeated under the same, or modified conditions, if desired.

Curves showing velocities and discharges.

25. Plate No. 5 shows graphically, for 6 inch and 9 inch pipes, laid at the flattest proposed gradients, the velocities and discharges with different depths of sewage. The quantities can be read at a glance, and it is probable that the diagrams will convey more information than many columns of figures.

The black lines are plotted from Santo Crimp's tables and the red lines represent the results of the experiments just described.

It will be seen that in every case the velocities and discharges as determined experimentally are slightly greater than those given by the tables, so that by using these tables a factor of safety is secured.

Transporting Power of Sewage flowing in Sewers laid at the flattest proposed Gradients.

Materials experimented with.

26. By means of the experiments just described, were measured the velocities of the sewage in 6 inch and 9 inch pipes, laid at the flattest gradients proposed.

From the results obtained, and in the light of experience with sewers, there is little doubt that all the flows, experimented with, would be able to transport silt in moderate quantities.

It was, however, considered advisable to verify this conclusion by experimenting with silt actually deposited in Madras sewers.

The silt used was that which had choked up some concrete pipes in Mylapore : it consisted almost wholly of quartz sand, with a small proportion of charcoal. By sifting through wire screens, it was found to be of the following degrees of fineness :—

Material No. I, passing $\frac{1}{8}$ inch mesh	88%
Material No. II, rejected by $\frac{1}{8}$ inch mesh passed by $\frac{1}{4}$ inch mesh	8%
Material No. III, rejected by $\frac{1}{4}$ inch mesh passed by 1 inch mesh	3%
Material No. IV, rejected by 1 inch mesh	1%
	100%

In addition to the silt, pieces of "granite" road metal, fragments of brick, etc., were experimented with as described below.

Results obtained by experiment.

27. The following results were obtained with 6 inch and 9 inch pipes laid at gradients of 1 in 135 and 1 in 230 respectively. The arrangements were the same as for the experiments on the velocities of flow, and are illustrated in Plate No. 4.

Half buckets of unsifted silt were introduced at several junctions : all the silt was gradually removed *by the minimum flow*. The finest material was carried away at once : the coarser particles were more gradually moved. The amount of the silt introduced at any one time, largely determined the period taken to carry it away—the greater the quantity of silt, the longer the time required.

Granite stones passing a $1\frac{1}{2}$ inch mesh and rejected by a 1 inch mesh and roughly cubical in shape, were moved along slowly, but were arrested by bad joints. Flat stones were not moved by the minimum flow, but were all flushed out by the maximum flow. With the mean flow a granite stone $2\frac{3}{4}$ inch $\times$ $2\frac{1}{4}$ inch $\times$ $1\frac{1}{2}$ inch with rounded edges passed all bad joints readily and moved all stones which had been arrested previously by the joints.

These experiments emphasize the great importance of laying all sewers true to line and level, and the evil consequences which follow bad laying and jointing. They also show that the shape of the material has a considerable influence in determining whether it shall be carried along or not. And further that the quantity of silt which can be transported per gallon of sewage flowing at a given velocity, is strictly limited.

Quantitative results.

28. The following were the velocities of silt and stones as measured.

Flow in gallons per minute.	Nature of Material.	Velocity of material in feet per second.	Mean velocity of clear liquid.
6 inch pipes.			
18·4 (minimum)	Silt Material No. I	1·62	1·73
36·8 (Mean)	Silt do. No. I	2·20	2·25
Half Full	Piece of flat brick	1·67	3·16
Do	Stone 2″ × 2″ × 2″	2·12	do
Do	Brick 4″ × 3″ × 2″	2·04	do
Do	Palmyra fruit (floating)	3·7	do
9 inch pipes.			
41·5 (Minimum)	Silt Material No. I	1·63	1·72
Do	do. II	1·47	do
Do	do. III	1·25	do

29. As a result of the above investigations, the writer is confirmed in his opinion that the gradients proposed are suitable, provided :—

1. That improper materials, including an excessive amount of silt, be excluded from the sewers. The means of doing this are described in the section dealing with connections to sewers.
2. That the heads of sewers and other special points be adequately flushed. (Dealt with under " Flushing " paragraphs 94×8.)
3. That reasonable supervision be exercised.

SECTION IV.

Pumping Stations and Plant.

Conditions governing the numbers and positions of the Pumping Stations.

30. Assuming the limiting gradients to be settled, then the fewer the stations at which the sewage is raised, the less will be the total first cost of the machinery, and the annual cost of its maintenance. On the other hand, the fewer the pumping stations, the greater will be the depth of the sewers, involving greater cost.

As a result of the work which has already been carried out by the Special Works Department in laying sewers, it is clear that deep sewers would be very expensive, owing partly to the difficulties of the ground—the large quantity of water combined with running sand—and partly to the difficulty in getting the trenches timbered in the manner that is necessary for deep sewers under such circumstances. The narrow streets and shallow foundations of buildings greatly enhance these troubles. From conversations with large English contractors it appears that the difficulty of getting good timbering is a common experience in the East, and, that, when heavy work has to be carried out, foremen timbermen are brought from Europe. The employment of European workmen would add greatly to the cost of deep sewers, which should be avoided as much as possible in Madras.

Pumping Stations required for South Tondiarpet.

31. Taking every consideration into account, it appears that about six feet below mean sea level is the lowest level at which it will be economical to lay sewers in Tondiarpet, although, if any great advantage were to be gained by going a little deeper, for a comparatively short length, there would be no hesitation in doing so.

Having determined the gradients to be adopted for the sewers, and the greatest depths at which the sewers are to be laid, the number of pumping stations and their positions are determined by the physiography of the district.

The sewers should be laid out so as to take the fullest possible advantage of every undulation and change in level of the ground surface.

In this way, using the proposed gradients, *three* pumping stations have been found sufficient to deal with the drainage of South Tondiarpet. The positions of these stations, and the areas drained by them are shown on Plate 10. With G.O. gradients, *seven* pumping stations would be necessary in the positions shown on Plate 2.

The principles which governed the sewer lay-out and the selection of the particular sites proposed for the pumping stations, and also the contributory reasons for their selection, are fully stated in Section X.

Oil Engines and centrifugal pumps recommended.

32. If the proposed gradients are used, it is recommended that oil engines and centrifugal pumps be employed for the pumping stations A, B and C, in South Tondiarpet, and for the large station at the Sewage Farm. The positions of the pumping stations, and the areas drained by A, B and C, are shown on Drawings Nos. 3 and 4 and on Plate 10.

If G. O. gradients are adopted, Shone system is recommended.

33. If the G.O. gradients should however be decided upon by Government, then seven pumping stations will be required, to drain the same area as can be drained to the three stations proposed.

A scheme has been worked out for the G.O. gradients, using the Shone System for raising the sewage : it is illustrated in Drawings Nos. 59, 60, and 61.

Estimates have also been prepared for this scheme. But the scheme is not recommended.

Reasons for recommending oil engines and centrifugal pumps.

34. The reasons for deciding on the pumping plants proposed may now be stated :—

For Pumping Stations A, B and C oil engines are advised, because they are considerably less in first cost than first class economical steam engines; and, in upkeep, oil engines will cost no more than economical steam engines, and considerably less than low grade steam engines. Suction gas engines, though of higher initial cost, can compete with oil engines where suitable fuel is obtainable at a low rate, and where drivers who understand them can be readily obtained : but neither of these conditions exists in Madras, and this class of engine cannot be recommended.

Centrifugal pumps are recommended, because they are suitable for raising screened sewage. Their first cost is low, and they are efficient and economical under the conditions of low and constant head, and approximately constant delivery per pump, which will exist at these stations.

Special suitability for Madras of the centrifugal pump and gravitation main system.

The pumping system designed and recommended, *viz.*:—that of low constant lift and head, with gravitation mains between pumping stations; is the only economical method by which centrifugal pumps can be used to lift and propel sewage over long distances. Centrifugal pumps forcing *sewage* through long lines of small mains, invariably shew a very poor efficiency; the work done under these conditions is commonly only equal to one-third of the engine power supplied; in other words, the efficiency is commonly but 33 per cent. With the system proposed, the pump efficiency should be at least 50 per cent. and will in all likelihood average more.

In England it is very rare to find centrifugal pumps forcing sewage through long lines of rising mains, and when such is the case, as for example at Newbury, the lift is low, the sewage free from silt, and the main used is so large for its work that the velocity is low and the skin friction small. This ensures that there shall be little variation of head and no high head due to friction. At Newbury, the *maximum* rate of flow in the rising main, about $1\frac{1}{2}$ miles long, is little over 1 foot per second, and the total lift is only about 20 feet. The reason why it is necessary to keep the velocity low, when forcing sewage through long mains is that the horse power and head required increase as the square of the velocity, and, with anything but low velocities, the maximum head would be great and the variations of head would be considerable and most deleterious to efficiency in pumping mains such as would be required for Tondiarpet. Under these conditions of high and greatly varying head centrifugal *sewage* pumps give but poor efficiency. There are high lift centrifugal pumps on the market, but they all are designed for clean water. To pump sewage that has passed through a one inch screen would require not only entirely special design, but the efficiency, as admitted by makers, would be much affected by the larger waterways that are necessary. The centrifugal pump is, for raising sewage, a low pressure pump.

Turbine pumps of the "Rees Roturbo" type are not suitable—except possibly in the largest sizes—to deal with Madras sewage which carries in suspension solid matter such as would soon choke the nozzles of the impellors.

I have never heard of any other system where groups of centrifugal pumps are utilised to pump at different points into one long main as at Madras : and it is an arrangement that I should never recommend.

Cast iron mains are much more costly in India than in England. In European countries cast iron mains of comparatively large sizes can be used with centrifugal pumps, and hence the head due to friction is kept low and—within small limits—constant, and the pumps then shew a fair efficiency. Rs. 30 per head is a fair average cost of Main Drainage in Europe, but in Madras, even Rs. 15 per head seems a very heavy burden, and we could not possibly afford to put in cast iron mains large enough to keep the friction head sufficiently low under all the varying rates of sewage pumping.

If small mains are used, the efficiency of centrifugal pumps will be too low. Expensive piston pumps are the only kind used in good practice to pump through long lines of main, and against high and variable heads. It is on this account that expensive piston pumps are to be installed at the Law College and Rayapuram Stations. The maximum head worked against by centrifugal pumps at 23 sewage pumping stations in England, averages out at only 24½ feet, the highest being 38, which is very close to the limit for good efficiency. At the Mylapore, Ice House Road and DeMellow's Road Pumping Stations in Madras where centrifugal pumps are used the varying head goes up to from 50 to 80 feet or more.

Now in Madras, very fortunately, brickwork sewers can be constructed far more cheaply than in Europe or America, and this has been one important factor in determining that the cheap centrifugal pump, with constant and low lift, and brickwork gravitation main, is the best and cheapest system for dealing with sewage in this city.

It is a favourite method in England to use centrifugal pumps to lift the sewage from a low level main sewer into a high level gravitation sewer whence the sewage commonly flows to the disposal works.

The drainage of Southend includes a station where centrifugal pumps are connected by a short rising main of very ample size to a gravitation sewer. Again, coming to the East, the new pumping station, which has been constructed near the harbour in Colombo, will be furnished with centrifugal pumps to lift the sewage from the incoming 3 ft. × 2 ft. low level sewer into the outgoing high level gravitation sewer also 3 ft. × 2 ft.

To Summarize the foregoing :—

(1) Centrifugal pumps are the cheapest and best for the small units required, if the heads are low and constant.

(2) Iron mains are most costly in Madras, and would render the cheap centrifugal pump unsuitable.

(3) Brickwork gravitation mains are very inexpensive in this city, and it is proposed to take full advantage of this fact, in all future operations.

Reasons why oil engines and centrifugal pumps have not always been successful in Madras.

35. It may be objected that oil engines and centrifugal pumps have not always proved satisfactory in Madras in the past, and that at the present time some Corporation plants of this description are not giving satisfactory service. The reply is that the pumps and engines were not designed for the work which they are doing. For instance, at Rayapuram the engines ordered were so much too small that the pumps had to be taken out, and others of smaller size substituted ; in consequence the present plant is unable to deal with the dry weather flow which reaches this station.

Further, the conditions of working the existing centrifugal pumps are quite unsuitable. Owing to the very defective deliveries, the long C.I. Main and other causes, the heads vary and are often too high for ordinary centrifugal pumps to work against with efficiency. In most cases only one pump can be used at a time : and this pump has to deal with a highly variable amount of sewage and to raise it against a head which increases as the quantity pumped increases.

These conditions existing at the old pumping stations are about the most unfavourable possible for centrifugal pumps driven by oil engines. In the proposed installations, the pumps will operate against a low head and a constant head ; and, by properly dividing the units, and by providing storage in the pump well, the quantity to be raised by each pump will be constant within a small margin. These are the best possible conditions for all pumps, but especially for centrifugal pumps driven by oil engines.

Further details of the pumping plant will be found in Section X.

Electrical pumping.

36. Electrical pumping is notoriously expensive. I have gone carefully into the question of electrical pumping for Tondiarpet, and I am of opinion that it would be much more costly than oil engine power. If electric power for lighting, tramways, and trade use were generated by the Corporation, it might be possible to make use of surplus power for pumping, but for pumping only, it would not be economical to erect a plant and engage an electrical engineer. The alternative of buying current from a local company would be costly and there would be the further disadvantage that the source of power would be outside the control of the Corporation. At Acton, London, where is one of the few electric driven sewage stations—it was considered necessary to have power brought separately to two switch boards, from two different large generating stations in order to provide against breakdown, and the stations in daily use belongs to the Municipality.

Shone System.

37. The " Shone " system of pumping or raising sewage by compressed air, is likewise not recommended if the gradients proposed in this Report are adopted, because of its high cost, both to instal and to maintain ; these costs are so high, that, where only three pumping stations are required, certain advantages possessed by the system are not worth its great extra cost.

Reasons for recommending the Shone System if G.O. gradients are adopted.

If however the G.O. gradients are adopted, making necessary seven pumping stations for South Tondiarpet, then the Shone system is recommended. The reason being that, if the number of stations is multiplied so greatly, the advantages of this system will outweigh its many disadvantages.

It is a general experience in the East that the question of using the Shone system is nearly always raised, wherever the conditions are at all suitable

for this method of lifting sewage. It is, therefore, likely to be raised in the case of the drainage of Madras, where the conditions are not unfavourable, if expense is no object.

The system will now be described, in order to anticipate questions, and to assist in making clear why the Shone system is recommended if the G.O. gradients are adopted. But let it be quite clear that the Shone system is not recommended if the proposed gradients are used.

The Shone System.

38. In the "Shone" system, sewage is raised by means of compressed air, generated by steam or other power at a central station, and then distributed through cast iron mains to the numerous sewage lifting stations, where it enters ejectors—an ejector being a form of compressed air pump. General.

This system has been used at Karachi and Rangoon, and for certain areas of Bombay and other places in the East: it has also been used on a small scale in England and Australia.

39. Drawing No. 59 shows the general arrangement of the system as applied to South Tondiarpet if the seven pumping stations already mentioned should be installed. The sewers of each of the seven areas would drain to one of the seven ejector pumping stations. Description of system. (Drawings 59, 60 & 61).

The central air compressing station is shown near ejector station B. From this point the air mains (shown in yellow) would convey the compressed air to the seven ejector stations, A, B, C, D, E, F and G; from these the air pressure would force the sewage through the iron sewage mains (shown in blue) into the main sewer leading to the farm pumping station.

The ejector stations would each contain two ejectors, either of which would be capable of lifting all the sewage which would drain to the station.

Drawing No. 60 shows a typical ejector station adapted for Tondiarpet conditions. The ejector itself consists of a cast iron vessel, the capacity of which is determined by the quantity of sewage to be dealt with, and may vary 50 gallons upwards.

40. Plate No. 6 illustrates a typical ejector in a cast iron chamber, or "tubbing," such as would be necessary in Madras. It will be seen that the sewage vessel is provided with an inlet pipe through which the sewage enters, an outlet pipe through which it is discharged, and a compressed air main through which air under pressure can be admitted into the top of the vessel. Description of Ejector. (Plate No. 6.)

In working, the sewage flows in by gravity until it has nearly filled the ejector, when the rising liquid automatically opens the valve on the compressed air main. The compressed air then rushes in, presses down on the surface of the sewage and drives the whole of the contents of the vessel through the outlet pipe at bottom. The sewage can only escape by the outlet pipe because the inlet is provided with a flap valve, which closes as soon as compressed air is admitted.

When nearly the whole of the contents of the ejector have been driven out, the compressed air is automatically cut off and an exhaust valve is opened

which allows it to escape. The sewage is again admitted through the inlet, and the cycle of operations is repeated so long as there is any sewage to deal with.

Advantages and disadvantages of the system.

41. As a sanitary appliance, the ejector is very successful, it has the great advantages of being automatic in action, requiring very little attention and being able to deal with unscreened sewage without any of the wear which occurs in pumps of other types.

The great disadvantage is the cost—the initial and running expenses are both high. The air compressing machinery, cast iron air mains, sealed sewage mains, ejectors, and ejector stations, are all costly, and the working expenses are high on account of the low efficiency. The depth to which the Tondiarpet ejectors would have to be sunk is also very great, in most cases not less than 27 feet—a costly undertaking in running sand.

The inherent low efficiency of the Shone System is a consequence of the nature of the system, which involves the following unavoidable losses :—

(1) Friction of the mechanism of engine and compressor.
(2) Heating of air during compression.
(3) Slip and clearance in compressor.
(4) Leakage from air mains and ejector valves.
(5) Slip and clearance in ejectors.
(6) Impossibility of using air expansively in the ejectors.
(7) Friction in long lines of compressed air mains.

Owing to these losses, the cost of running plants on the Shone System has usually proved considerably greater than was originally anticipated. Careful experiments have been made at Karachi, Bombay, Sydney and other places in order to locate the losses and reduce them, as far as possible. These experiments have indicated that between 25 and 35 per cent. is the highest efficiency obtainable, and that in ordinary use it might not be safe to count on more than 20 per cent. The actual measured efficiencies were :—

Karachi—	
When first installed	25·7 %
After a few years use	18·5 %
After overhauling	26·3 %
Sydney—	
When first installed	35·00 %
Bombay	22·3 %

The above efficiences compare badly with the 50 per cent. or more that should be obtained normally in the system proposed.

To the losses due to want of efficiency, must be added the drop from the sewer invert into the ejector, which, in the case of ejectors suitable for Tondiarpet, would be about 7 feet.

Shone System recommended if G.O. gradients are used.

42. Notwithstanding these serious objections it has been thought worth while to consider very carefully the application of this system to Tondiarpet, and, if G.O. gradients should be adopted, the Shone system is recommended in preference to any other method of raising the sewage. For, with G.O. gradients, as already stated, no less than seven pumping stations will be required

for South Tondiarpet. With this number of stations, the power required at each is so small that, for separate engines and pumps, the efficiency of the plant would be very low, and in consequence the initial cost per unit of work done would be very high. And, when the cost of land, silt pits, and screening chambers is taken into account, and also the cost of up-keep,—fuel, oil, repairs and a large staff of drivers—it will be found that the advantages of separate engines and pumps vanish as compared with the Shone system, which is practically automatic, requires little attention, and for which silt pits and screening chambers are unnecessary. Further, as the ejector stations are wholly underground, they may be constructed under the roadway, and no land need be acquired for them. But I must repeat here, that the Shone system is a costly, if not the most costly, of all methods of sewage raising where there is a considerable volume of liquid to be lifted at each station, and, if my proposals be adopted, the Shone system will be out of the question.

SECTION V.

House Drainage and House Connections.

First Class House Drainage.

(Drawings Nos. 43, 44 and 45—Plates Nos. 7, 7*a*, 7*b* and 8.)

43. There is little doubt that the water carriage system, with underground drains and water closets will be eventually adopted in Madras. It has the following advantages amongst others :— Water carriage should be gradually adopted.

(1) The excreta and urine, instead of polluting the air of houses and streets, goes at once to the sewer ; and in half a minute or so after deposition is safely on its way from human habitations.

(2) The water closet is incomparably cleaner, nicer, and more sanitary to use for removing excreta than is any other known form of sanitary appliance.

(3) An enormous amount of filthy hand scavenging is abolished. This work is very degrading, yet employs hundreds of men, women and children.

(4) The great expenditure on conservancy of night-soil by bullock carts and coolies is not required. Night-soil depots and trenching are done away with by using flushing latrines and water closets.

But the water carriage system can be introduced only gradually because :—

(1) The expense of installing the system at once would be quite prohibitive. When water closet appliances are made as cheaply in India, as in England, I have little doubt their use will become universal, even in the poorest houses, as now in England.

(2) The mass of the inhabitants of Madras are not yet sufficiently educated in the principles of sanitation to understand the importance of working the system properly.

But wherever practicable, water closets should be installed in all hotels and clubs, in the houses of Europeans, and in those of all educated Indians who can afford them. The great cleanliness would be much appreciated and should create a general demand in the community for the European type of water carriage system. This is the experience of Bombay, and it will probably be the experience of Madras as the wealth of its people increases, bringing in its train a greater desire for comfort and a greater dislike of offensive nuisances. Of course it is absolutely essential that a water-supply, and flushing tanks of at least two gallons capacity, should be installed wherever the water carriage system with water closets is put in. One-and-a-half gallon tanks have been used for workmen's dwellings in England, but have been found to be rather too small for the best results. Water closets should be used in First class houses.

44. Where water closets are installed in Madras the arrangements would be the same practically as are used in England, and generally in Europe and America. This system will be referred to as First class House Drainage ; it is illustrated in Plate No. 7, and in more detail on Drawing No. 43, where First class type of house drainage (Drawing No. 43, Plate No. 7.)

are shewn the gas-intercepting siphons, disconnecting and inspection manholes, junctions, cleaning arms, open discharge grids for sinks, kitchens, and baths, siltcatchers on inlets from stable, kitchen and washing place, ventilation pipes, soil pipes, etc.

The Corporation would provide the connection from the sewer to an intercepting siphon, to be fixed at the side of the road. The owner of the premises would bear the cost of the remainder of the work, which would have to be carried out in accordance with the bye-laws which have yet to be framed. A set of bye-laws for Water-supply and Drainage will be drafted by the Special Engineer for the consideration of the Corporation after orders have been passed on this scheme, and on the Water-supply Distribution Scheme.

Second Class House Drainage.

Second class type of house drainage. (Drawing No. 44, Plate No. 7 A.)

45. In Second Class house drainage the open channel is replaced by a pipe having properly trapped connections, and much trouble has been taken to design house drains and connections on these lines, suited to Madras.

Plate 7A illustrates a house drained in this way. The system may be applied to houses which are intermediate between the first class houses, and the third class of houses in which live the bulk of the inhabitants of Madras.

As examples of cases to which the system is applicable, may be mentioned detached and semi-detached houses and bungalows, which are provided with gardens too small to allow the drainage to be dealt with inside the compounds without creating a nuisance.

There are few houses of this description in Tondiarpet, but in other parts of Madras, notably in Egmore, Vepery and Purasawakum, there are houses of good class which are discharging sullage into earth side-drains. The drainage of these houses, including night-soil and sullage, should be conveyed to the sewer by water carriage, and, where the owners are not prepared to instal the First Class Type illustrated in Plate No. 7, they should be encouraged to put in the Second Class Type, illustrated in Plate No. 7A.

Third Class House Drainage.

46. It is anticipated that for years to come the houses in which first or second class drainage is used will be few in number. Therefore much thought has been given to the drainage of the ordinary small house of Madras.

House drains and house connections.

In what follows, it will be convenient to consider the house drainage as made up of two parts.—

(1) *House Drains* by which the sewage is delivered to the side of the street.

(2) *House connections* which convey the sewage from the edge of the street to the sewer.

At present the Corporation lays the house connection and the siphon trap, and the owner provides the house drain.

Existing house drains

In the poorer houses the drain is usually a brick-in-mortar channel of inferior construction, generally square in section, and frequently in such a bad state of repair, that solid matter is arrested and liquid matter soaks into

the soft brickwork and the surrounding ground, thus producing highly insanitary conditions. In hundreds of cases there is on the premises a well which is almost certain to be found polluted by the soakage. These conditions should be radically altered, for they cause a high death-rate and much sickness.

Objections to covered pipe house drains for the majority of houses.

47. Most reluctantly the conclusion has been reached that underground pipe house drainage is not at present suitable for the majority of the houses of Madras, because—

(1) It would mean a complete alteration of the existing drains of every-house, a measure which would meet with great opposition from the occupiers.

(2) The expense of the connections would in many cases be very great in proportion to the value of the houses—cheap underground drainage for a third class house would cost about Rs. 200.

(3) Owing to the way in which the houses are built together, drainage to the back is impracticable. The covered pipe drain would, therefore, have to be led to the front right through the house. This would be not only difficult, but also dangerous and costly work, because of the likelihood of damage to houses caused by digging trenches close to, and, in many cases, under the house walls, for the foundations of the numerous small one storey houses are neither deep nor well constructed. Furthermore it would be necessary to surround the pipes completely with 6 inches of good concrete, and this would add to the expense.

(4) Flushing would be absolutely necessary, and would entail a water service connection and flushing cistern for every house. It has yet to be decided whether it will be advisable to provide a separate water service to every existing house.

(5) The success of underground house drainage depends directly on its intelligent use. Deleterious matters such as sand, ashes, and garbage, should not be admitted into the system. If materials such as those referred to were introduced, the traps would become choked, the floors of the houses would be flooded with sullage, and exceedingly insanitary conditions would be established. Every entrance to an underground pipe drain must be provided with a siphon ; and the siphon must be protected by both a silt-catcher and a grating, to keep it from being blocked up by sand, ashes, rags, leaf plates, broken bits of bamboo, garbage, etc. These gratings and silt-catchers would have to be fixed inside the houses, and would require attention which at present they would never get. Underground pipe drainage inside poor class houses, was tried and found to be a failure at Bombay. All the grids, and siphons, and the drains themselves, became quickly stopped up ; and after vainly trying to get the system used more intelligently, all the underground house drainage had to be taken up ; and open channels were substituted.

Third class house drainage—by open drains. (Drawing 45, Plate 7 B.)

48. For these reasons the conclusion has been reluctantly reached, that underground pipe house drains would at present be quite impracticable in the majority of Madras houses.

Except where the owners are willing and able to put in a proper drainage system with all necessary traps and appliances, the writer is of opinion that house drainage by open drains should be adopted.

Such open drains entail the separate removal of solid excreta—a grave defect of the system—but, in almost all cases, the existing insanitary latrines can be converted at small cost into flushing latrines, of the cheap but simple and sanitary type shown on Plate 7 B, and Drawing 45.

A separate rain water drain, discharging into the road-side drain or ditch, will be required for every third class house. Some pains have been taken to devise arrangements by which one drain may be used to carry both the rain-water and sewage, and yet ensure that excess rain-water shall be excluded from the sewers. For the connection of side drains of Paracherries and minor roads where no sewers are provided, such an apparatus has been designed and experimented with, and has given satisfactory results.

But, while there would be no difficulty in adapting such arrangements to house connections in a town having a system of underground storm water drains, they are applicable to but few house connections in Madras, and provision for separate sewage and rain-water drains must therefore be made. The proposed form of Third Class house drainage is shown in detail on Drawing No. 45, and is illustrated on Plate No. 7 B.

Necessity for separating rain-water from sewage.

On the drawings and plate referred to, the rain-water drain is coloured green, the sewage drain is shewn in yellow. The object of having two drains is to separate rain and roof water from sewage, that is from sullage, washings, urine, and all fouled water. This separation is absolutely necessary because the rain-water during the monsoon is very much in excess of the sewage. If sewers were designed to carry the rain water as well as the sewage, they would have to be of great size, their cost would be enormous, and they would run nearly empty for eleven months of the year ; the monsoon being restricted to only a short period. As an example of the relation of rain water to sewage flow, take a house with a roof and courtyard area of 1000 square feet. Assuming one-third to drain into the road, then two thirds or 667 square feet will drain into the sewer. As the courtyards and roofs are impermeable, it follows that, if 1 inch of rain falls in an hour, then the water flowing to the sewer will be $667 \times 1/12$ cubic feet per hour or at the rate of

$$\frac{667 \times 24 \times 6\frac{1}{4}}{12} = 8338 \text{ gallons per 24 hours.}$$

If there are 10 persons living in the house, then the average rate of sewage flow, at 25 gallons per head per day, will be 250 gallons per 24 hours, and the rainwater will be $\frac{8338}{250}$ or 33·4 times as great as the average dry weather flow. Rain-water, therefore, must be rigorously excluded from sewers and house drains.

At present, when it rains in Madras the rain-water from the roofs pours on to the courtyards and discharges by the common drain of each house ; as much water as can, gets into the sewers through the house connections, and the rest finds its way into the side drains, and helps to flood the roads.

The sewers thus become quickly gorged, and the pumps are then overpowered at all the existing stations. It is of course plain that this state of things cannot be permitted in the future drainage of Madras.

A method adopted in some hilly cities is to provide numerous stormwater overflows on the sewers, thus permitting the use of comparatively small sewers, which overflow when an excess of rain-water enters them.

But this method is impracticable in Madras because there is nowhere for the overflows to discharge, on account of the low elevation of the land, which in many cases requires the sewers to be laid below Mean Sea Level. On this account, and in view of the fact that all sewage has to be pumped, it has been laid down rightly that, in Madras, sewage should be separated as completely as possible from rain-water, and that the sewers should be designed to deal with sewage alone.

To separate sewage from rain-water is not difficult in the First and Second classes of house drainage, where the house drains are covered; but for reasons already given, it is unlikely that covered house drains will be largely used in Madras for many years to come. In the meantime, with the open drains proposed, it is necessary to lay a separate rain-water drain as shown in detail on Drawing No. 45 and Plate No. 7 B, in order to exclude from house drains the rain-water which falls on the courtyards, and on the area of the roofs draining to them.

The separation of rain-water and sewage will be effected chiefly by small brick or concrete curbs, applied to the courtyards. These curbs are shewn red. They divide the court into washing space, and rain-water space. Rain falling on the roofs will pour off the eaves, fall on to the proper part of the courtyards, and flow at once into the open "U" shaped drain (coloured green) by which it will find exit into the side drain of the street. The soiled water from washing places, and that from household utensils rinsed under the tap, will be directed by the curbs into the sewage drain (coloured yellow). The washings and urine from the urinal, and from the latrine, will also flow into the sewage drain.

A good deal of washing is done on the verandahs surrounding courtyards; a very small open channel will therefore be made round the margin of each courtyard, and will be protected from rain-water by the usual curb. This little channel from the verandah, it will be seen, empties into the sewage drain.

By these means a practical working separation of rain and sewage will be effected. No doubt defective cases will occur, but for these an allowance was made when determining the size of the new sewers.

Near the street end of the sewage drain, will be placed an iron grating of a shape designed to allow the passage of silt, but, at the same time to catch all large objects which may be carelessly or wilfully thrown into the drain.

The grating will, as a rule, be made as in Fig. X, Drawing 45, the object being to catch sticks, leafplates, etc., without arresting the flow of the sewage and its silt transporting powers. The present house drain gratings are continually blocked up, and cause a length or stagnant sewage to back up frequently in the house drain. They are too small and close, and are very difficult to clean.

The rain-water and sewage drains are spoken of above as being *open*. But on the plan they are seen to be not entirely open. There are several reasons for this. The sewage drain should be closed wherever there is danger of rain-water entering it. The rain-water drain should be closed wherever there would be danger of sewage entering. Governing these two principles is that of free access. Free access to all drains and sanitary fittings is an axiom of modern work ; and if the proposed third class house drainage is examined, it will be seen that there is no drain or part of a drain that cannot be quickly examined and easily cleaned if necessary. If a bucket of water is thrown down the sewage drain once or twice, in a day, there should be no smell, and no unhealthiness ; where it can be afforded, a small flushing tank at the head of the open drain would be very beneficial.

Before coming to final conclusions on house drainage, the houses of a number of natives of different castes were carefully inspected, and numerous enquires made as to domestic habits of cooking, washing, etc., which affect drains and latrines. In none of the houses visited did there appear to be likelihood of difficulty in applying the methods shewn on Plate 8 and on drawing No. 45.

In cases where the courtyards are so small as not to permit division by curbs, or where the roofing presents difficulties, a "spouting" will have to be put along the eaves to take the roof water into its proper drain.

The amount of rain falling on courtyard washing places will be so small as to be negligible ; it will form a trifling portion of the allowance for rain-water made when designing the sewers.

Installation of Flushout Latrines and W C.'s in houses with third class drainage.

Although underground pipe drains from end to end of the closely built up houses are not recommended for the reasons given above, yet there will be no difficulty in fixing flush-out latrines or water closets for those who desire them, and are willing to pay for them.

In fact every encouragement should be given to secure their adoption, for by this means the excreta and urine would be conveyed to the sewer at once, in a cleanly way, without any of the nuisance caused by the insanitary latrine now everywhere in use.

In such cases the flush-out latrine or water closet should be situated next to the road, so that a short length of cast iron pipe can be used to take the sewage direct to the sewer connection, without passing through the silt-catcher or sullage water siphon.

Plate No. 7B and the plan on drawing No. 45 show in dotted red lines how a cheap flushing latrine of either a good plain cemented trough type, or of the better glazed pan type, can be substituted for the ordinary insanitary squatting wall with its accompanying smell, unsightliness, and hand scavenging.

A modern water closet of the European type can be put in with ease if desired, and is strongly recommended where there are upstair latrines. In fact water closets in such cases should be compulsory.

Work should be carried out under definite rules and under supervision.

49. House drainage should be carried out in accordance with definite rules and under proper supervision. No house should be allowed to be built until drainage plans have been submitted and approved. No new house should be allowed to be occupied until the house drainage has been examined, and a certificate of approval granted. Where the drains of existing houses are unsatisfactory,

the owners should be served with notices to put them into a condition which will satisfy the Health Officer and the Engineer. The cost in all such cases to be borne by the owner. The work whether done by the Corporation or by the owner, should be under the supervision of a Corporation Officer having expert knowledge and experience of modern drainage.

Bye-laws for new buildings.

Rules—forming part of the bye-laws already referred to—should be drawn up, and should contain the following provisions:—

(1) The open drains shall be constructed according to the type design adopted by the Corporation. The bottom part shall consist of lime surki concrete (lime 2 parts, surki 1 part sand 3 parts broken brick or stone 12 parts) and shall be lined with 4 and 6 inch half round glazed stoneware pipes in the case of the sewage and rain-water drains respectively. The remaining part of the drain shall be of brickwork with a rendering of 2 parts Portland Cement to 3 parts sand, at least $\frac{1}{2}$ inch thick, and trowelled to a smooth surface.

(2) The flattest gradient at which these drains may be laid is 1 in 100.

(3) At the lower end of the sewage drain, *i.e.*, on the inside of the street wall of the building, a substantial grating of the Corporation's approved design shall be built in on the drain in such a manner as to prevent improper materials entering the house connection to the sewer.

(4) No water closet or any other arrangement for the removal of night-soil shall, under any circumstances, be connected with the open drain.

(5) The Corporation shall have power to reject inferior materials, and to have bad work pulled out.

Bye-laws for old buildings.

The bye-laws should also include a separate series of clauses to deal with existing buildings. These clauses should require the construction of separate rain-water drains. Otherwise they should not require that new drains shall be provided for old buildings, but should lay down the method of construction where it is necessary to put in new drains to insure sanitary conditions, to remedy a nuisance, or where an owner wishes to relay existing drains, or to put in new drains.

Recapitulation.

50. To recapitulate : The plans of houses in Madras are so varied that it is impossible to prepare a few designs which will meet every case. The drainage of each house will have to receive separate consideration.

It has been possible, however, to decide the principles which should govern the design. These are illustrated in Plates 7, 7A and 7B and drawings 43, 44, and 45 which refer to three typical cases, *viz.* :—

First class (Plate No. 7) for houses furnished with water closets, baths, lavatories, and sinks drained on modern European lines.

Second class (Plate No. 7A) for houses where modern underground drains are possible but where European appliances are not required or cannot be afforded.

Third class (Plate No. 7B) for the ordinary small house of Madras in which it would be most unwise to use underground drainage.

Besides these three classes, there are the paracherries and huts where each habitation cannot be provided with a separate connection to the sewers. These will be dealt with in the next section.

House Connections.

51. As already stated, a "House Connection" in this Report refers to the short drain which connects the house drain with the sewer. It is laid under the roadway, from the end of the house drain to the sewer.

1st and 2nd Class House Connections.

House connection for houses with first and second class types of drainage.

The sewer connections of houses provided with first and second class types of drainage will follow the usual European lines. Where necessary, separate rain-water drains will be laid to ensure the exclusion of the rain-water from the sewer. Disconnecting chambers, modern intercepting siphon traps, air inlets, silt catchers, etc., will of course be provided. Type examples of these connections are illustrated on Plates 7 and 7A and on Drawings 43 and 44 which are self-explanatory, and need not be described in detail here.

3rd Class House Connections.

House connection for houses with third class type of drainage. (Plate No. 8).

52. Much more important to Madras as a whole are the connections for houses having the third class type of drainage. A great deal of thought has been devoted to overcoming the defects of the present form of connection, and, as a result, the proposed method now to be described is recommended.

The type of connection proposed for houses with open drains is shewn on Plate 8. It begins with a 4 inch pipe, of stoneware or cast iron according to circumstances. Starting on the inside of the house wall, this pipe will convey the sewage to the silt catcher whence it will pass through the siphon and into the 4 inch stoneware pipe which is fitted with a cleaning arm. The 4 inch pipe will be laid at a minimum gradient of 1 in 40, and will be connected with the sewer by an oblique branch, or by a suitable junction at a manhole, so that the flow from the connection will not interfere with the flow in the sewer, but will, rather, assist it.

Comparison with existing type of house connection.

53. The present type of house connection is unsatisfactory in many ways. For purposes of comparison, it is shewn side by side with the new type on Plate No. 8. The most important improvements are :—

1. The introduction of a silt-catcher.
2. The insertion of a cleaning arm.
3. The improved method of making the junction with the sewer.
4. The elimination of the 1 inch ventilating pipe.
5. The provision of access to the pipe connecting the house drain with the trap.

Dealing with these points in order :—

Silt-catcher.

Apparatus for excluding the silt from the sewers is greatly needed. To insure that no silt, or only a negligible quantity, shall enter from the house drains, it is proposed to fix a "silt-catcher," or silt trap, at the head of every house connection. The silt-catcher is of a type which has been specially designed for Madras, and is described in detail in Section VI paragraphs 73 to 83.

There is little doubt that this device will be very valuable both for keeping silt out of the sewers, and for preventing the choking of the siphons. The deposition of silt has caused an immense reduction in the carrying power of the

sewers of Madras, and the regular choking of the siphons is a frequent cause of the nuisance of overflow of sewage on to the roads.

Cleaning arm.

56. A stoppage of the pipe leading from the siphon to the sewer is not uncommon. When it occurs in the present form of house connection, it is necessary to dig down to the pipe and break it open ; a proceeding which is both expensive and unsatisfactory, because it is difficult to make anything but a poor repair to the pipe, once it is broken ; the road surface also is damaged.

The fault lies in the absence of a *cleaning arm ;* and a more up-to-date pattern of siphon trap provided with a cleaning arm would be a great improvement. As, however, there are no less than 15,000 siphons of the present type in stock, for which Rs. 64,000 was paid, it is proposed, to insert a 35 degree junction next to the siphon, as shewn on the drawings and plates. This will allow cleaning rods to be introduced and will be an effective cleaning arm. The stopper of the cleaning arm will be sealed with weak mortar, to allow removal.

Improved connection to sewer.

57. As will be seen from Plate No. 8, the existing connections are brought in vertically on the top of the sewer. This method produces bad results, because the stream of liquid from the house drain entering at right angles checks the flow in the sewer, and a deposit is formed. Furthermore, the falling liquid produces splashing, which liberates the bacteria in the sewage, and makes the sewer gas much more harmful than it would be otherwise.

There is also a great likelihood of the crown of the sewer being broken owing to the weight which rests upon it, and the extra weight which is transmitted by the rigid vertical pipe when a heavy weight—such as that of a steam roller—passes along the road. Suspicious fractures have already been unearthed and noted.

In the new type proposed, the connection will be made, occasionally at manholes, but generally by means of oblique junctions, which will guide the flow of sewage from the drain so that it will not interfere with the flow in the sewer, but will rather increase its velocity. Where the main sewer is deep, shallow rider sewers will be laid to receive the house drains. These arrangements are fully described in Section IX.

Ventilating pipes not required on connections.

58. One inch vent pipes, such as those which disfigure many of the roads of Madras, will not be required in the new house Connections. It may, however, be noted here that the immediate removal of the existing one inch pipes is deprecated, because they serve to release the air which is imprisoned in the connections during those periods of the day when there is a backing up of sewage. If this air in the connections is not provided with a way of escape, it will cause the siphons to overflow into the roads. See plate 12, fig. 9 and paras. 105-6. The pipes therefore perform a useful function, though they are not suitable as ventilators, for which purpose they are absurdly small, and have so many bends that they are certain to become choked after being in use for a short time. This was pointed out officially and fully explained in my Quarterly Report No. 4, embodying investigation and advice as to maintaining the old sewers, pending their remedy.

Access to pipe from house drain to silt-catcher.

59. The short iron pipes, which bring the sewage from the house connection to the siphon trap, occasionally become blocked, and, in order to free them, the house-holders have to break either the pipes, or, more commonly, the masonry into which they are built. That this may not be necessary in the new connections, means of access are provided, so that cleaning rods may be used to clear away obstructions.

SECTION VI.

Public Latrines—Night Soil Depots—Paracherry Drainage—Connections of side drains to sewers—Exclusion of silt and storm water—Silt-catchers.

Public Latrines.

60. None of the new methods of house drainage which have been described will be applied to paracherries : these must be dealt with by means of side drains. But public latrines of a suitable type should be provided in sufficient numbers for the population of paracherries, for those who have no proper dwelling place, and for use of the numerous coolies who come from outlying villages to work in the town. Necessity for more latrines.

61. The existing latrines are too few in number, and the great majority are insanitary, are wanting in privacy, and are repellant to those who have to use them. Improved type required.

Owing to the nature of these structures, an extravagant amount of supervision would be necessary to ensure efficient cleaning. In fact their condition generally does credit to the department which controls them ; but no inherently insanitary appliance, such as the ordinary Madras dry latrine, can be anything but a nuisance, no matter how good the supervision may be.

Inspection will convince any one that a better latrine is very badly wanted. The two chief reasons why so much excreta is deposited in the side drains and on the road-ways of Madras are :—

1. The scarcity of latrines of any kind.
2. The repellant nature of most of the existing latrines—their scanty provision for washing, their absolute lack of privacy, their dirtiness, their stench.

Decent, smaller, and more numerous latrines are badly wanted. The few existing flushing latrines are wasteful of water ; at one of them visited, there were three fair sized taps running full bore. If latrines of this kind are multiplied, an immense waste of water will ensue. The latrine problem forms part and parcel of the drainage and sanitation of Madras ; it also affects water-supply appreciably.

62. Particulars are therefore given on drawing No. 47 of a latrine to suit Madras conditions. It has been designed after making numerous inquiries of natives of different castes. These enquiries have led to the conclusion that the Indian appreciates privacy in these matters as much as the European, and it is important to encourage a sense of decency, and a desire for good sanitation, especially among the classes that use public latrines. Proposed type of Latrine.

The new latrines are intended, wherever possible, to be built in connection with either a new or an existing public tap, washing place, or cattle trough. All waste water now lost at a these places will then be utilised to flush out the new and re-constructed latrines.

The arrangement and full details of the proposed type are given on drawing No. 47, which is fairly self-explanatory. The new-latrines will be divided into a number of compartments, all opening on to a common passage. As the result of experiment, the sizes of the compartments have been fixed at 2 feet 6 inches

square. The positions for taps, foot places, uppers, and doors have also been determined by experiment. Short automatic swing-to doors of light teak boarding will give privacy. The tops of the doors will be 4ft. 9ins. high, but the doors themselves will be only 3ft. 9ins. deep and will end 12 inches above the floor. Owing to the limits of the latrine corridor, no one will see too much either over or beneath these doors except by unusual effort. On the other hand, it will be easy to ascertain whether a compartment is occupied or not. The user of the new latrine would push open a pair of these small doors, which would swing-to gently behind him, he would then find his feet in position on the only standing room in the compartment. Facing him, but only 12 inches above floor level, would be a small automatic water tap. While a person is using the latrine, this tap will comfortably support the right hand, leaving the left hand free to wash with. These washings will fall on a narrow trough-like area, and cleanse it of urine ; they will also keep clean and wet, that very steep part of the cemented latrine upper, on which the excreta falls, causing the deposit to slide downward at once into the 6" covered pipe channel which passes under each compartment. This arrangement prevents splashing, and also soiling of vertical parts difficult to clean. The user of the latrine having washed, stands up, steps backward into the passage, and the doors swing-to again. The ablution tap will close itself when the hand is taken from it. Cheap iron taps of the kind required have been in use in England for many years.

The 6 inch stoneware pipe drain is flushed clean by the waste water from the drinking fountain and washing place, which, as will be seen from the drawing, is in the open air, at one end of the building, but quite outside it. Before entering the drain, the waste water is passed through a silt-catcher to free it from silt which may have been used for cleaning pots, or brought on to the platform by the feet of those using it. From the silt-catcher the clear water passes into a tipping box, which discharges its contents almost instantaneously as soon as it is filled up to a predetermined point ; and rights itself again immediately the discharge is completed.

The frequency of tipping, and consequent flushing, depends on the rate at which water is wasted at the washing place. This will probably be sufficiently rapid at all hours of the day, but, if at any time more flushing is desirable, it can be secured by turning on one of the public taps for as long as may be necessary. This would be done by the attendant who would be responsible for the cleanliness of a number of latrines.

On leaving the latrine, the flush water, carrying all the urine and fæces with it, passes through an intercepting siphon and into the sewer.

A superstructure has been designed which will be well ventilated. It is also inexpensive.

The ablution water saved by the automatic taps, and the saving that might be effected in night soil work and bullock cart conservancy, should easily repay the cost of the new latrines.

Cleanliness of streets improved by latrines.

63. The provision of latrines is intimately connected with the cleanliness of the streets of Madras, which, as everyone agrees, might be greatly improved. It is an offence punishable by law to use the streets as latrines, and when an

adequate number of suitable conveniences have been erected, a few convictions and severe sentences would have a great effect in preventing the offence. But under the existing conditions, a magistrate would undoubtedly find that, in many parts of the city there were extenuating circumstances, inasmuch as it is laid down by Clause 222 of the Municipal Act that "the President shall, so far as the means at his disposal permit, provide and maintain in proper and convenient places a sufficient number of public latrines and urinals so constructed as not to be a nuisance."

Doubtless the reason why a sufficient number of latrines has not been provided is that sufficient funds have not been available ; but now that the sanitation of the city is being considered seriously, the great importance of latrines must not be lost sight of.

Old side drains.

64. The problem of what to do with the side drains in streets where sewers have been laid will also be solved in a great measure by the provision of latrines. There is no doubt that these drains should be used for rainwater, though it would be well to modify many of them so as to make them more like the "water tables" of European cities. This is the plan which is being followed with success in Bombay.

It may be explained that "water tables" are the shallow channels or gutters, constructed at each side of a road to carry off the rainwater. They are made of brickwork, granite setts, Cuddapah slabs, concrete, or of other suitable materials.

Unfortunately under present conditions, the old side drains when left open, are found to be used as latrines, and, owing to their shape, they are difficult to clean. The same remarks that have been made about the roads generally also apply to the side drains.

It is impossible to blame the homeless people, or the village workmen far from home, if in the absence of latrines, they make use of the nearest and most convenient places. But, if sufficient latrines of a suitable type were established, then offenders might be prosecuted with a reasonable anticipation that they would be severely punished, and the offence would become as rare as in cities which are provided with proper conveniences.

Night Soil Depots (Drawing No. 62).

Proper method of introducing night-soil into sewers.

65. The conservancy of night soil is a very insanitary, objectionable, and out-of-date method of removing fæces ; but a good many years must pass before night-soil conservancy can be abolished in Madras. Excreta should of course be flushed into a sewer within a minute or two of deposition ; it then travels forward aided and enveloped by an allotted amount of water. Excreta collected in a cart should never be put directly into a sewer ; because it is not sufficiently liquid to flow easily ; in Madras there is a strong additional reason, for the scavenger when collecting, picks up with the excreta quantities of sand and silt, mingled with fragments of brick and mortar, sticks, stones, leaf plates, ashes, tin cans, and other refuse, that should on no account be allowed to enter a sewer.

Night-soil depots, arranged to admit excreta safely into the sewers, are much wanted in Madras.

Necessity for night-soil depots.

Night-soil scavengers will always be tempted to use manholes for getting rid of their burdens when depots are too few, and too far apart. Such cases have already been detected by this department.

The Health Officer of the City has also drawn my attention to the difficulty he has in disposing of night-soil. The cost of conservancy for long distances, and the necessary trenching must be very considerable. With a growing population the difficulty will increase rapidly if not remedied; and, as the question is directly connected with sewerage, it is now dealt with.

Depots for the safe admittance of night-soil into sewers can be made at comparatively small cost; and, if well placed, they should save a great deal of the present unavoidable carting, and will entirely abolish the unwholesome trenching in.

Night-soil depot designed for Madras.

Drawing No. 62 shews a depot designed specially to deal with Madras night-soil. The conservancy cart is backed up to one of the two receiving places, and is there tipped; the excreta falls directly on to a cast iron grating, the surface of which is about 2 feet below ground level in order to prevent splashing; an abundant stream of water from a pendant flexible jet-piece is directed into the cart, which is sluiced clean; the cart then moves away and the jet is directed on to the deposited excreta, quickly forcing it down through the $1\frac{1}{2}''$ spaces between the bars. In this way, the excreta is at once separated from all large refuse such as sticks, cans, and leaf plates. This refuse is left on the bars, from which it can be removed easily by a proper rake, adapted to draw the rubbish up the masonry slope on to the floor level. It will then be lifted into a cart and sent to the destructor; or a small single cell destructor could be easily attached to a depot if desired. The excreta, as it is driven by the water jet through the grating, becomes broken up, mingled with water, and reduced more or less to a fairly thin consistency. In this state it falls through the grating into a smooth cemented shoot, which promptly delivers it through the division wall into what may be called the "flushing invert." This invert is a wide channel, having a narrow rounded bottom sloping quickly towards the inlet to the sewer. The lower portion of the invert bottom is occupied by a series of narrow cast iron gratings, of cross bars spaced $\frac{3}{4}$ of an inch apart; the cemented invert is continued, at a lower level, beneath this long narrow grating. When a considerable quantity of sluiced and screened night-soil has collected in the invert trough, and after, if needed, it has been stirred up (from the convenient standing platform provided), a self-closing valve is held open to give direct access into a sewer, and, at the same time the flushing chamber is brought into action at the top end of the trough. The whole mass of excreta, in a liquid state, then pours into the sewer and is carried away. All refuse that escaped the large bars of the receiving places will now be seen caught on the long narrow grating in the bottom of the cemented trough; from which if can be readily drawn up by rake, on to the floor of the depot.

A pit to intercept sand and silt is also provided, so that nothing but water and night-soil may enter the sewers.

The carting floors will be of well dressed and grouted stone pitching which is sloped to the trough to facilitate cleansing; the mixing floor will be of concrete, similarly sloped to assist washing. All corners are rounded, and every

precaution has been taken in the design, to ensure sanitary conditions, and to reduce smell as much as possible in the night-soil depots. A cast iron curb, imbedded in concrete, is provided for each receiving place, in order to prevent injury from cart wheels. The jets are to be controlled by small simple hand wheel valves. The supply pipes to jets and flushing tank are arranged so that no fouling is likely to occur to the water mains, under the existing conditions of intermittent supply, and if required an overhead storage tank can be included.

Connections of Side Drains to Sewers.

Necessity for side drain connections.

66. My study of the drainage of Madras has convinced me that, for a long time to come—for at least one, and probably many generations—some side drains will be a necessity. In no other way is it practicable to drain the paracherries and other collections of temporary habitations, which are liable to be cleared away at any time. A simple and cheap form of side drain can be made of Cuddapah slabs bedded on a thin layer of chunam concrete as shown on plate 12, Fig. 1. If later on the road should be sewered, it will be only necessary to lower one side of the drain and a suitable water table for rainwater will be formed at small expense as shown in Fig. 2.

Cuddapah slab side drains having a rounded cement invert have been constructed in Madras by the Special Works Department, and have proved successful, and less costly than masonry. Sewage side drains that are liable to have road metal and sand washed into them, will be protected by making one side wall of the drain a little higher than road level, that is, by providing the drain with low curb throughout its length, as shewn in the cross section, Fig. 1 on Plate 12. At present much labour is expended in clearing road detritus out of side drains, after each heavy rainfall : the curb will render most of this work unnecessar

Silt and storm water must be excluded from the sewers.

67. Side drains for Paracherries are unavoidable, but it is most important that their connections to the sewers should be made properly. In the existing system many connections are made direct to the sewers, thus allowing silt, road metal, rubbish, and storm water to enter freely. In other cases there are silt pits, but in no case, as far as is known, has any attempt been made to exclude storm water.

It was quite obvious from the first that both silt and storm water should be excluded from the sewers, and, after making a number of experiments, two forms of apparatus, have been designed which will effect what is required in a simple and cheap manner.

Silt trap and storm water separator. (Drawing No. 48 and Plate No. 9.)

68. One of the arrangements is shown in detail on drawing No. 48 and both are shewn on Plate No. 9. The former, which will be the more commonly used, has the following essential parts, *viz.*, a silt-catching chamber, a sewage or upper weir, a rainwater or lower weir, a weir closer, and a siphon or gas interceptor.

In ordinary dry weather, sewage entering from a side drain will pass first through the silt chamber, in which the velocity will be so reduced that silt, no longer able to remain in suspension, will fall to the bottom. The dip stone—a Cuddapah slab—will stop large floating objects such as cocoanuts or leaf plates. The sewage having passed through the silt chamber will arrive at the upper weir, over which it will fall into the small cross channel below : this will convey the sewage to the siphon, whence it will flow down a 6 inch drain into the sewer.

When rain falls, the volume of liquid passing over the upper weir will be increased, dilution will become great, and the flow will then suddenly leap right over the lower weir, to discharge steadily into the ditch or storm water drain at the road side ; and no liquid will be entering the sewer.

The sudden leaping is greatly aided by the slope which leads the water to the upper weir ; and in the actual apparatus the leap is found to take place quite suddenly and completely.

The leap weir method of separation is well known, but the slope for producing the sudden jump is an improvement. In the ordinary leap weir, exclusion of water from the sewer would take place too gradually, the leap would at first be only partial, and before complete separation and cutting off had been effected, a great quantity of storm water would enter the sewer ; and if, as generally would be the case, many slow acting weirs were in operation, the volume of rainwater entering the sewers would be much more than the allowance of one-third of the maximum sewage. In the weir proposed, a small increase over the maximum sewage flow will cause complete cutting off ; and the extra flow coming in just before the sudden leap takes place will be counterbalanced by the complete shutting off that immediately follows. This extra flow lasting usually a few minutes only, will tail out, and its arrival at the pump well will be spread over a much longer time than it took to enter the sewer. The effect in the sewer will be somewhat analogous to throwing a bucket of water into the upper end of a long trough ; the water is emptied out of the bucket in a second or two, and at first fills a portion of the trough, but it tails out, and the bucket of water will be found to take whole minutes to run out at the lower end of the trough.

Rainwater separator for side drain connections, which are liable to flooding.

69. A greater difficulty, however, than that of the slow leap weir, remained to be overcome. In Madras, the lack of any rainwater drainage system causes flooding in hundreds of streets during the heavier rainfalls of the monsoon. The writer made a special visit to Tondiarpet during a violent fall of rain, in order to investigate the state of things, and waded hundreds of yards through the flooded streets. It was obvious that any form of leap weir or separator would be completely submerged on these occasions ; an ordinary leaping weir would be put quite out of working, its action would be reversed and the space between the two weirs would form an opening down which an immense quantity of silty water would rush into the sewers ; in fact the " separator " would be little better than one of those direct openings which are amongst the chief causes of the immediate overwhelming rush to the pump wells of water and silt, which now takes place in Madras every time it rains at all heavily.

New separator fitted with weir-closer.

70. The " weir-closer" shewn on drawing No. 48 has been devised to meet the difficulty. If the water in the road side ditch should rise too high, then the large piece of wood—forming part of the closer—is floated up, causing the weir-door to shut down, and complete closing is effected before the flood water reaches the lower weir ; the higher the water rises and the deeper the apparatus is covered—the tighter will the closing piece shut down. When the flood subsides, the weirs are automatically re-opened by the weir-closer rising, as the counterbalancing block of wood sinks back into its normal position. The device has the merits of cheapness and accessibility ; there is nothing likely to get out of order, and, if made as designed, it will be too strong to be easily damaged. The

small cast iron siphon covers will be made so that little leakage will occur through them, even if the whole apparatus becomes submerged.

71. Separators of this new type fitted with weir-closers, will be used for all paracherry connections, but they will also be used immediately to remedy a number of existing side drain connections to sewers, in different parts of Madras: for these side drains at present are led into the sewers with no provision of any kind for keeping out flood water; there are in fact connections which may be described as mere holes leading into the sewers; it is therefore not surprising that the present pumping engines are all quickly overcome every time it rains. The inflow into the sewers of silt and even road metal, which now takes place is of course most deleterious, and aids the inefficient gradients to produce the lamentable silting up which is taking place in almost all the sewers of Madras. It may be pointed out that all parts of the new separator are readily accessible, that the cross channel is fitted with a stoppered cleaning eye, that the weir-closer can be lifted right out by unlocking, and the silt chamber in each case will be of a size small enough to prevent stagnation of sewage, but large enough to store the silt brought down by a week's dry weather flow. Many of the catch pits fixed on the side drains of Madras are too large; the sewage only creeps through them, stagnates, and causes complaints of smell. Catch pits will be substantially covered, yet readily accessible for cleaning. All silt pit bottoms will be rounded and designed for easy cleaning, so that square corners are not left full of old silt. In the typical silt pit and separator, the bottom is shown to be formed so that all silt will fall readily towards the cleaning scoop. But in the future, catchpits should be emptied inoffensively by a cart pump with flexible tube and silt nozzle. Small platforms, with curbs and draining-gaps, will be provided for the sticks and large refuse caught by the gratings (See Plate 9.)

Where separators will be used.

The separator just described is for use where a ditch or rain-water drain will permit a workable difference of level, or "drop," between the sewage surface in the paracherry or other side drain, and the rain-water surface in the ditch or storm water channel.

But there are many cases in Madras, where no such convenient drop exists and a second type of separator and weir closer has been thought out to meet this difficulty. The apparatus is similar in many respects to the first type; it has the same kind of silt pits, separating weirs, siphons, and covers; but the closer is rivetted to, and actuated by, a hollow metal cylinder which floats in the clear side of the silt pit. When the dry weather flow is exceeded, the sewage rises an inch or two in the silt pit, causing immediate closing of the opening between the weirs. Storm water is then diverted into a bye-pass and none can enter the sewer. The silt chamber float, and weir closer, are protected from leaves, rags, etc., by means of one of the new gratings, fixed in the side drain just before it terminates in the silt pit, and further protection is afforded by means of a second close-barred grating fixed on the clear side of the silt pit. The apparatus is inexpensive and simple, and should require little attention.

A working model can be seen at Napier Park, and the side drains of Patters Road have been connected by means of this device, which is illustrated by a small plan and section on Plate 9.

Surface water drainage of Madras.

72. Ultimately, the storm water of Madras must be dealt with; the existing ditches, the old large masonry drains, the existing masonry sewage side drains, must all be studied, utilised, and linked up; but this work cannot be efficiently dealt with, until the complete contoured map of Madras, required primarily to deal with the defective city drainage—has been made. It is hoped to finish most of this map during the next few months, and a number of data has been collected for it while preparing the Tondiarpet Scheme and considering the city drainage.

Silt-Catchers. (Drawing No. 46 and Plate 9A.)

Necessity for silt-catchers.

73. Examination of the existing sewers of Madras shewed that no measures had been taken to exclude sand and ashes used for pot scouring.

Far too flat to deal with even the best of sewage, the daily addition of silt poured in from every house drain has caused the inevitable breakdown of the existing sewers to come quickly. Silt should, as far as possible, be excluded from drains, sewers and pumping stations. In Madras it is now allowed to enter the system freely. It has be removed somewhere : and this is done partially—

1. At the siphons, which regularly become choked with silt, and require a large cleaning staff.
2. In the sewers, an expensive operation requiring a permanent gang of cleaners. In fact so bad has the silting up of sewers become, that an official has been appointed to supervise the cleaning of the sewers.
3. At the pumping stations, where deposits are formed in the pump wells, causing stoppage of the pumps and making it necessary to employ a regular staff of divers at every pumping station, to clean the foot valves.

What is not removed at these three stages is pumped through the main, and wears out the pumps in the process.

Evils resulting from silt in drains and sewers.

74. Silt in quantity, always, and quickly, stops up every form of siphon—and a siphon is a necessity on every house drain—silt infallibly puts flat sewers right out of action, daily menaces with stoppage even the best graded sewers, wears out their inverts, pours into the pumping wells every time it rains, cuts and wears away the interior of the pumps, and commonly when there is a storm buries the suctions and stops the pumps just when they are most required. The exclusion of silt in quantity is therefore highly necessary, its absolute exclusion is extremely difficult, but a small amount—which nevertheless would mostly accumulate in sewers laid at bad gradients—is got rid of safely by sewers which have proper slopes and velocities, such as are proposed for Tondiarpet. (See also experiments with silt paragraphs 26 to 28). This unavoidable silt will be caught in the new silt pits to be introduced at all pumping stations.

The exclusion of the silt brought down by open side drains has already been considered The exclusion of the silt from the house drains will now be dealt with.

Silt to be caught before reaching house drain Siphon.

75. It is obvious that silt should not be allowed to enter and block up the house drain siphon. It should be caught before it gets to the siphon, and when caught it should be capable of ready removal, not only from the drain, but from the street and the proximity of human beings. For such silt is saturated

with sewage, contains minute bits of organic matter, and has germs in it which are dangerous to health. If put on the road side, it is unsightly and emits smell, but, what is much worse, this foul silt dries, turns into an offensive and dangerous dust, is blown about, and enters the eyes, mouth and lungs of the passer by; it also penetrates the houses, and everywhere settles on food. Clearly, this silt should be conserved without touching the roadway, and be at once removed in a covered cart. The apparatus and method used should be as cheap, simple, durable, practical and fool proof as possible. Nothing could be found on the market which fulfilled the requirements of Madras, for there is no demand for such an apparatus in European or American house drainage.

Silt-catcher designed to meet Madras conditions.

76. An apparatus has therefore been designed to meet the case; experiments were commenced in October last with a first actual model silt-catcher, and since then other smaller models have been made, with a view to obtaining economy. Several of the later models have for some weeks been in use on ordinary house drains.

Figs. 3, 4, and 5, on Plate 9A, shew two models of the proposed silt-catcher. In figs. 1 and 2, the cone shaped type is seen in position. Plate 8 shews the relative positions of the silt-catcher, sewer gas intercepting siphon, cleaning arms, and the pipe connection from the house drain to the sewer.

Description of silt-catcher.

77. The silt-catcher is a form of sheet steel or iron bucket, inserted on the house drain. All house sewage has to pass through this bucket, and while flowing through, it deposits its silt in the bucket.

The clarified sewage on leaving the bucket, flows forward a few inches and drops into the ordinary siphon, passing thence down the 4 inch stone-ware pipes which convey it to the sewer.

The silt-catcher bucket is fitted with a diaphragm or thin "baffle plate" fixed vertically across it, extending 5 or 6 inches above the bucket rim and also about the same distance down, inside the bucket. The diaphragm is not fixed across the centre of the bucket top, but, instead, divides it on plan into two unequal segments of a circle, the smaller of which is the inlet side.

The inlet side is still further contracted by what will be called a "current deflector," rivetted along the bottom edge of the diaphragm (see Plate 9A, Fig. 4). When the silt-catcher bucket is in position on its seating in the block of brickwork, the bucket rim is about one inch below the end of the in-coming house drain.

Action of silt catcher.

78. The sewage from the house drain, as shewn in Fig. 2, strikes the diaphragm and is deflected, its current is broken up, it passes in a slow stream under the diaphragm, and rises upward still more slowly, for the area of the outlet side is greater than that of the inlet side. The silt, much heavier than water, settles and accumulates at the bottom of the bucket.

The silt will now, if left to itself, gradually fill the bucket up to the bottom of the diaphragm; it should be emptied regularly before this occurs, but, if neglected, the silt accumulates on the inlet side only, because the diffused sewage current and pressure are too weak to push it forward from beneath the diaphragm and make a clear way for the sewage flow; at the same time, there

is a considerable filtration through the obstructing silt, and this releases liquid and keeps the sewage level almost even on either side the diaphragm, until the inlet side is deeply silted up ; filtration then decreases, and at last almost ceases ; the incoming sewage backs up—as shown in Fig. 2—against the upper part of the diaphragm and fills the end of the house drain : finally, if the silt-catcher be still further neglected, sewage begins to run out through the "tell-tale" hole, into the road or side ditch.

Brickwork block for silt-catcher and siphon.

79. The silt-catcher and siphon are enclosed in a small block of brickwork, measuring on its top, 2 feet 3 inches by 18 inches, which size is slightly smaller than the blocks now enclosing the old siphons of Madras, for those measure 2 feet 2 inches by 2 feet 2 inches. Access to the silt buckets will be obtained by a small cast iron cover door, 7 inches in diameter, and to the siphon by a similar door 6 inches diameter. Of the latter there is a considerable stock left over from the late "New Drainage works."

Method of emptying and replacing silt-catchers.

80. To empty a silt-catcher is very simple, the small circular hinged door is thrown open, the handle—above sewage level—is seized, and the bucket withdrawn, at first gently, to give time for the water standing over the silt to run off into the masonry cavity by means of the hole in the bucket side (Fig. 4) and the channel marked "*surplus water channel*" Fig. 2. The bucket is then turned upside down over the cart ; the silt slides out, the bucket is returned, the surplus water rushes back into the bucket, the lid is slammed down, and the cart proceeds to the next silt-catcher. The cart referred to is a suitable hand cart which should always accompany the silt-catcher cleaners, so that the silt may be emptied into the cart at once, and not placed as at present by the side of the road, to await a bullock cart which may be many hours in coming.

Less labour required for emptying silt-catchers than for cleaning siphons.

81. At present every siphon in Madras has to be cleaned of its silt, in most cases daily. The smallest pattern of silt-catcher has a considerably greater capacity than a four inch siphon and should not need emptying more often than every third day—judging by those now at work. The diameter of all silt-catchers will be the same, but in cases where extra large or specially small amounts of silt are to be caught, silt-catchers having more or less than the ordinary depth will be used.

The labour of emptying silt catchers should therefore be much less than that of daily unstopping and cleaning siphons, for to comfortably empty and replace a silt-catcher takes only 30 seconds.

Material for construction of silt-catchers and cost.

82. The buckets should be made of iron at least 1/16" thick, well galvanised, and they might be thoroughly dipped in pitch and tar and re-dipped every 6 or 12 months at a depot : a sufficient number of duplicates being kept in hand to allow the work to be carried on constantly by three or four men.

It is probable that the average cost of a silt-catcher and its cover will not exceed Rs. 4, and for large orders the price should be less.

Further applications of silt-catchers.

A silt-catcher of the above type will also be used to exclude the sand of washing places, from entering waste water flushing chambers and latrine flushing boxes ; the positions of silt-catchers in these cases are shewn on drawings Nos. 41 and 47. All drains from stables and other buildings which are likely to receive sand or silt, should be provided with silt-catchers.

SECTION VII.

Manholes—Lampholes—Special Manholes—Flushing—Ventilation.

Manholes.

Uses of Manholes.

83. The word "Manhole" is now used by sewerage engineers to mean the ordinary chamber built at intervals on the line of every sewer. The functions of such chambers—or manholes—are many. They allow access for examination and cleaning, and they provide convenient points for connecting ventilation inlets and outlets to the sewers. Manholes in modern work, are spaced not more than about 300 feet apart on straight lengths of street sewers; they are also placed at all angles in the pipe lines, so that by going down a manhole with a light, a man can see from chamber to chamber. Thus all bends in sewers are formed in the bottoms of manholes: and the pipe-lines between them are perfectly straight, and can be seen through from end to end. In modern work, the junction of a minor sewer with a major sewer is invariably made by means of a curved "U" channel formed in the bottom of a manhole.

In order to connect a small shallow street sewer to a deeper intercepting sewer, or a high level to a low level sewer, a manhole is always essential. Manholes again, are used very largely throughout Great Britain, Europe, and America to act as air inlets, to a system of tall sewer ventilating columns. This being the most usual and satisfactory way of ventilating a main drainage system.

Removeable covers should always be provided.

84. For over fifty years certainly, it has been the universal custom in England, to provide all manholes with removeable iron covers, either closed or grated. It seems incredible, but it is true, that in Madras, within the last few years, several thousands of manholes have been permanently covered over, with expensive granite stones overlaid by earth and road metal; with the result that all indications of the positions of the manholes soon became obliterated, nowhere could the sewers be freely examined, and, when it was desired to obtain access to them trial holes had to be dug, the road surface damaged, and considerable delay and expense incurred on each occasion.

Inverts of manholes.

85. Inverts, ten years ago, used to be made of half the pipe depth, and the benchings started at half-pipe level; but later and better practice, is to make them U shaped and of the full depth of the sewer pipes. (See Plate 12, Figs. 3, 3*a*, and 4). Where a smaller sewer enters a larger sewer, (by means of a manhole), or where a sewer receives two lesser sewers, the roofs or soffits of the smaller incoming pipes are fixed at the same level as that of the larger incoming and outgoing pipes; so that when the volume in the larger pipe becomes great, it will not "back up" or interfere with the discharge of the smaller pipes.

Although a very large number of the existing manholes have been examined, yet, *in no single instance has the writer been able to see the bottom;* but by probing with bamboos and iron bars, and by sending coolies down, it has been found so far that no proper inverts have been formed; indeed most of the bottoms are quite flat, and even if these sewers were not choked up and overcharged, the sewage would spread out over the manhole bottoms and form a permanent stagnant deposit, through which the stream of sewage would have to find its way.

Sewer soffits should be at same level.

The principle of putting the soffits of pipes entering a manhole at the same level has also been largely neglected in Madras. For example, it was found during work done by my Department at Sadayappa Moodaly Street, in Mylapore, that the invert of a 6 inch sewer having a fall of 1 in 330 had been brought in level with the invert of a 12 inch sewer; consequently, when a depth of 9 inches of sewage is flowing along this 12 inch pipe sewer, the mouth of the 6 inch sewer will be submerged three inches, and the sewer itself will be backed up, or flooded, for a length of about 250 feet. All backing up of sewers, and deposit and stagnancy in manholes, inevitably result in generation of foul smell, and silting up.

Proper inverts in manholes.

Specimen inverts for the new work have been constructed at Napier Park, for the instruction of the maistries, who are building modern manholes for the Special Works Department. In Tondiarpet the bottoms of all manholes will be *inverted* to the proper depth, as shewn on the drawings. These manhole "inverts" are smooth U shaped channels, the bottoms of which are generally formed of glazed stoneware half pipes of the same radius as the pipes they serve to connect, and of the full depth of the pipes; so that if the pipes ever run full, the sewage will remain confined to its proper channel, and will not spread out in the manhole and deposit filth on the "benchings." In dry ground these inverts can be made in concrete plastered with cement; in wet ground it is preferable to use glazed stoneware half pipes for the bottom portion of the "U" channel, the straight sides above the curve being cement plastered. On removing a manhole cover in a well designed sewerage system, one should see only clean brickwork, clean benchings, and the sewage flowing through the manhole bottom, confined in its appointed narrow inverts. A typical manhole with "drop" connection is shown on Plate 12, Figs. 3 and 4. It will be noticed in the designs that all the benchings are well sloped to aid self-cleanliness.

Type depends on conditions.

86. Designs are given on drawings Nos. 29 to 37 for both square and round types of manholes, but wherever possible it is proposed to use the round type because this form is both the stronger and the more economical. For all sewer depths of six feet or so and upwards, the round manhole is suitable; for lesser depths the square type is preferable, for the reason that with very small depths, the circular manhole becomes too steeply conical.

Manholes at Sewer heads.

87. Where the sewer head is of slight depth, a square manhole, long and shallow will be used; of the form shewn on drawing No. 29, which illustrates a manhole of the minimum depth allowable. Every sewer head will be ventilated by means of a 6 inch stoneware pipe leading from the manhole to the foot of a 6 inch ventilating shaft, taken up well above the tops of the neighbouring buildings.

88. An internal diameter of 4 feet 6 inches at the bottom, will in nearly all cases be sufficient for the Tondiarpet manholes. This same diameter has been found in England to give good results. Brickwork 9 inches thick would be quite strong enough for even the deepest circular manholes proposed for Tondiarpet, but, in deep manholes, this thickness would give hardly enough protection against the percolation of ground water, and it may be found necessary to make all manholes 14 inches thick up to a little above ground water level. The estimates have therefore been taken out on this basis.

Prevention of percolation of ground water.

To further prevent percolation of ground water, the outside of the manholes will be roughly plastered with an hydraulic mortar, which will also preserve the brickwork from decay ; for this reason too, the interiors of the manhole walls will be thinly and smoothly plastered with good hydraulic mortar. The granite stones removed from existing defective manholes in other divisions of Madras, will be utilised largely in the shallow square manholes for Tondiarpet. The stones will be used to reduce size and roof-in the chambers, ready to receive their cast iron covers. Four patterns of cast iron manhole covers and frames have been designed, two for circular and two for square manholes. (See Drawings 30 & 40). Two are closed covers and two are grated iron ventilating covers. The closed and grated covers are interchangeable ; so that an open cover can be exchanged for a closed cover, or *vice versa*, in a few minutes, and without the least disturbance of the road or cover frames. The closed covers are fitted with the usual wood blocks. The open grated covers are to be provided with removeable " dirt boxes " of galvanized iron to catch the road dust, sand, and small stones, which would otherwise fall through into the sewers and do harm.

Closed and open grated M. H. covers to be used.

Lampholes.

89. When the street bends and angles are very frequent, it is often possible and economical to replace certain manholes by "lampholes," which are much cheaper.

Lampholes an economy.

Normally, a manhole is placed at every change of sewer direction. It is placed there so that the sewer-bend can be made in the manhole invert ; but, as a rule, the bend coincides with a street junction, and the ordinary manhole provides commonly for two requirements, *i.e.*, (1) for a change of direction, and (2) for the junction of two or more sewers. But where the manhole is situated between two others not more than 300 feet apart, and is required solely for a change of direction, it may properly be replaced by a "lamphole." A design for a lamphole for Tondiarpet is shewn in drawing No. 38. The sewer bend is made at the base of the lamphole in a very small chamber. Leading up to the road surface, from this little chamber, is a 9 inch or 12 inch stoneware pipe shaft, its upper end being surrounded by brickwork, and the whole protected with a closed or open grated street cover—very like a manhole cover, but smaller.

Proper positions for Lampholes.

This cover can be readily taken off. A lamp, if lowered down the pipe shaft, will be visible from the manholes, on either side the lamphole. In the sketch Fig. 5 Plate 12, the lampholes C and E, might be used legitimately instead of manholes. If a light were lowered down the shaft of C, it would be visible to men looking through the pipe lines from B to C or D to C, and

in the event of any injury or stoppage, it could be at once determined if the trouble were between B and C, or C and D. It may be mentioned here that stoppages in ordinary English and American sewers are very uncommon events.

If open grated covers (with dirt boxes) are provided, the lampholes can be used as air inlets of the ventilation system : otherwise the closed cover would be used. It will be noticed in the design that settlement of the cover, or the passage of a steam roller, will not transmit any weight to the pipe column or to the sewer from which it springs.

Special Manholes.

"Drop" Manholes (Drawing Nos. 31, 32, 34 and 35).

90. The main intercepting sewers, on their way to the pumping stations, will often be in deep cutting where they pass the ends of many streets drained by shallow sewers : see the sketch. Fig. 6, Plate 12.

It would be wasteful and also unnecessary to commence the short street sewer from the level of the deep intercepting sewer : so a "drop" is put in ; the sewage of the shallow sewer--on arrival at the deep sewer manhole—will drop down a vertical pipe shaft, into a "P trap" at its foot, and flow thence through a deep curved invert channel into the large sewer. Typical designs of drop manholes to meet different conditions are shown on drawings 31, 34 and 35 and in Figs. 3 and 4, Plate 12. The object of the P trap is to form a water cushion for the falling sewage and so prevent excessive friction and rush into the large sewer ; the arrangement works very well in practice, and should always be used where there is a drop connection. The shallow sewer is continued beyond the top of the drop-shaft, and terminates in an open end on the inside of the deep manhole. Through this opening into the manhole, the shallow sewer can be inspected, and, if obstruction should ever take place, the opening would be used for the passage of the sewer cleaning rods. It is in reality a cleaning and inspection arm.

In South Tondiarpet, about 200 small sewers will discharge into deeper sewers by means of such "Drop Manholes." Light flap-valves of thin metal are sometimes placed on the ends of the shallow sewers entering drop-manholes, to prevent, or partially prevent, the passage up the small street sewers of air from the main sewers ; this is sometimes needed in hilly towns--such as Rochdale, England—where flaps prevent escape of sewer air in excessive quantities at any point. When flaps are used, a small air inlet is placed on the street sewer just above the flap ; it is usually a 9 inch pipe shaft, with an open grated cover to admit the air, very much like a lamphole. It is almost certain, however, that such flaps will not be required in Tondiarpet ; but their use has been considered, and they are therefore mentioned here.

Shallow rider sewers provided to avoid deep house drains.

91. It is neither economical, nor good practice, to drain houses direct into deep intercepting sewers : especially is this so in Madras, where nearly all streets and roads are narrow, and the substratum is sand saturated with water. When the depth of a main sewer exceeds about eleven or twelve feet, the individual cost and difficulty of each house connection becomes so increased, that it is better to provide the street with a second sewer,—a shallow six inch diameter "rider" sewer,—laid parallel to the main sewer.

The house drainage of the particular street is then economically shallow, is separated from the deep main drainage, and can be executed without difficulty and without excessive cost. In practice it has always been found most difficult to

get satisfactory deep house connections made in water-logged ground. In a street 20 feet wide, traversed by a main sewer 15 feet deep, the house connections have to come up some 14 feet vertically, in a horizontal length of only 12 to 15 feet. The house drains are then so steep that each must be surrounded with concrete for some distance up; and even then, in actual practice, there is found to be frequent subsequent settlement and breaking of house drain joints, and often there is fracture at or near the junction with the main; in addition, a deep and awkward trench is required for each house drain. The filled-in earth, however carefully rammed, always slides a little down the nearly vertical slope of the drain trench, and, owing to the friction against the pipes, and especially the pipe collars, it exerts a great pull on the house drain and a considerable pressure on the sewer itself. This causes fracture. Such settlement or fracture generally results in stoppage, and repair is costly, and requires pumping etc.: but, what is of much more serious consequence, the abundant subsoil water finds its way into the sewers through the defects just described, and every drop of this leakage would, in the case of Tondiarpet, have to be pumped. Such leaks if not accompanied by serious fracture and stoppages are almost impossible to locate and remedy. For these reasons it has been decided to use rider sewers in Tondiarpet wherever required.

Shallow and deep sewers using same manholes.

92. A common practice in rider sewering is to put in separate small manholes and a completely separate street sewer, above and parallel to the deep main, and this is very well where the roads are broad, and economy not so vital; but to meet Madras conditions, a different arrangement has been thought out by which the small rider sewers will use the manholes of the deep sewers, but at a higher level. There will thus be only one set of manholes and manhole covers in any one road.

The designs for this arrangement are given on drawings 35, 36 and 37, where it is shewn that the small street sewers will be carried through and across the upper part of the deep manholes, by means of granite stone bearers, or side chambers; and that, when the small sewer, after passing across several deep manholes has gone deep enough, it will enter a "drop manhole," either by itself, or with other shallow rider sewers coming from other directions; the collected high level street sewage will then shoot down a stoneware-pipe drop-shaft common to all and ending in the P trap at the bottom of the deep manhole, where the sewage will be properly directed into the main sewer by means of a curved invert.

At the same time there will be perfect access, inspection points, and ventilation given to the small rider sewers by these arrangements, and all house connections will be made easily, at normal cost, and without risk of subsoil leakage, or need for concreting. Additional connections, certain to be required, will also be made with ease in the future. Junctions, securely stoppered against subsoil water, will be inserted in all pipe sewers where they are likely to be needed in years to come.

Multiple Manholes.

93. The first portion of the 24 inch cast iron main, *out-going* from A to B, is seen to be laid along streets which contain deep intercepting sewers *coming in* to Station A; thus in the same street there are shewn to be two large sewers. But, in addition, there are the 6 inch diameter shallow rider street sewers just described above, and 6 inch sewers coming in from side streets. The same set of manholes will be used for all four sewers, as shewn on

drawing No. 36. On removing a cover of one of these manholes, the sewage of the rider street sewer will be seen flowing through the manhole in a small chambering about 4 feet down. Just below this is the inspection eye of a side street sewer which is received in the manhole bottom by means of a drop-shaft.

The larger low level sewage flow, joined in the manhole bottom by the sewage of the side street, will be seen flowing westwards to Pumping Station A. On the other side of the manhole, and comparatively near the surface, will be seen an opening into the 24 inch cast iron main, and the sewage from the pumps at A will here be seen flowing on its way to Station B. The end of the side street sewer in this case is too low to permit it being led into the 24 inch cast iron main, and so to Pumping Station "B"; but wherever possible this has been arranged to be done. The high level 6 inch rider sewer will not be terminated by a drop-shaft in the low level 12 inch sewer going to Station A, but will be led across into the 24 inch main at the most favourable manhole. The trench work will be arranged as far as possible to let each sewer rest on solid ground ; but it will probably be necessary to leave some timber in at different important points along this triple sewer trench, in order to prevent movement while the ground becomes re-consolidated. An allowance for this timber has been made in the estimates.

The deep stoneware intercepting sewer will be laid and filled over first, then the cast iron main will be put down, and finally the small street sewers and house drains will be laid. These rather complex conditions, however, only obtain for a length of some 400 yards. Nine of these multiple manholes will be needed in this short distance—Nos. A. P. 1 to A. P. 9—on account of the close network of streets in the locality.

Drawing No. 37 shews a manhole on the 24 inch cast iron gravitation sewer, in this case it has become sufficiently deep to take in the sewage of both rider and side street sewers. The drawing shews how two 6 inch rider sewers and one-side street sewer, are brought in by means of an inspection side-chamber and drop-shaft.

Sewer Flushing.

Flushing chamber fed by waste water from public taps, etc.

94. At the present time in Madras, a great quantity of water is being wasted daily from about a thousand public taps. This water should be utilised for sewer flushing, and on drawing No. 41 is shewn a complete design for a typical automatic flushing chamber, to be fed from the spillings of a public fountain.

The design is made to suit the case of a shallow sewer head, but with slight alteration, it can be applied to flush sewers of any depth, and the arrangement can be fed from any public tap, cattle trough, or place where water is at present spilt or wasted.

Where the sewer head is very shallow, the standing enclosure round the public tap will be raised a foot above road level, and will be provided with one or two approach steps. All spillings will drain to the flushing tank, first passing through a silt-catcher, in order to remove sand and silt brought on to the washing place by persons feet, or which results from scouring of pots and pans. After passing through the silt-catcher, all waste water goes direct into the flushing chamber, which it fills up to a certain point, compressing as it rises, the air imprisoned in

the siphon, until equilibrium is suddenly upset by the escape of a large bubble of air ; and at once the gradually accumulated water of the tank rushes over the siphon, and the sewer is flushed. The flushing tank is cut off from sewer gas by means of the stoneware intercepting siphon-trap shewn on the drawing : all flush water passes through this trap as it enters the sewer.

Where the ends of sewers to be flushed are three feet six inches or a little more in depth, then the tops of the flushing tanks will be finished off level with the road surface, and the standing places of the public taps will be at normal level, that is, at no higher than ordinary road level, but protected from flood water by a curb of proper height. For deeper sewers, the tanks will be entirely underground.

Flushing tanks will be made of sizes suitable for the work required of them, and, where no convenient public tap can be utilized, it will be necessary to provide an ordinary water-supply ; a proper drip tap being set to make the tank discharge once or twice a day or as may be desired.

95. It is not essential that *all* sewers should be artificially and specially flushed. There are thousands of well laid and graded street sewers in England, which have never been flushed by special arrangements since the day they were put in, years ago ; yet these sewers remain clean and in good order. It is highly probable that the majority of the Tondiarpet sewers, if carried out as designed, will also keep themselves clean without flushing. On the other hand there are some sewers of South Tondiarpet which are designed to be provided with flushing chambers. For some years flushing chambers will also be needed where the main sewers will at present terminate, to await extension in the future ; as for instance at those points where the intercepting sewers running north from Station A, come to the edge of their extension area. These main sewers (see drawing No. 4) will not get their full volume of sewage for some years to come, and will periodically require flushing, to augment their flow and aid their self-cleansing powers. The letters "F. C.," are used on the plans to indicate the positions of essential flushing chambers. But in the new scheme, it will be possible to flush from *every* sewer head, whenever desired. During hot weather and long spells of drought, sewer flushing is beneficial and desirable ; for at those times sewage is more concentrated, decomposes quickly, gives off more gas, and is reduced in self-cleansing quantity.

Cases where special flushing arrangements are provided.

96. A simple cheap form of portable flushing disk has therefore been designed, to enable all manholes at the upper ends of sewers to be used as flushing chambers.

Arrangement proposed for flushing heads of Sewers.

When a street sewer is to be flushed, a cart-load of water will be brought to the manhole at its head. The manhole cover will be removed and the outlet pipe closed, the water cart will then charge the manhole, the disc will be removed and flushing will take place. Where there is a convenient hydrant, the manhole may be filled from it by means of a hose pipe.

97. The only objection to this system is that any house drains, connected directly into sewer head manholes used for flushing, would be backed up temporarily ; compressing in them sewer air which would be forced in the

No house connections to enter flushing manholes.

form of gas bubbles through the house siphons ; but this trouble can be avoided by bringing no house drains into these sewer-head manholes, and it is proposed to make it a strict rule, in Tondiarpet, that no house drains shall enter flushing manholes.

The above mentioned evil of sewage backing up house drains, is a serious objection to the use as flushing chambers of ordinary manholes on the line of a sewer. Such use is effected by temporarily closing the outgoing sewer pipe of a manhole, and so allowing the sewage to " back up " considerably ; the collected sewage is then suddenly released, and flushes the sewer below the manhole ; but, unfortunately, it also causes silting in the ponded-up length above and forces the sewer gas through many siphons as it becomes imprisoned and compressed by the rising sewage. This ponding-up also fouls the benchings and walls of the manholes, and the soffit or roof of the sewer ; on all these surfaces a thick deposit is left, which decomposes and increases the amounts of gas and smell. Flushing by means of any manholes except those at sewer heads is unscientific and is not recommended for Tondiarpet or any other divisions of Madras. It is only allowable as a temporary measure in bad systems.

Capacity of flushing tanks.

98. The determination of the precise quantities of water necessary for flushing sewers of various sizes and gradients has been somewhat neglected in the past ; and only a few meagre statistics have so far been given to the engineering world. The capacity of a flushing tank depends chiefly on three factors, *viz.*, on the size, the length, and the gradient, of the sewer it is to serve.

One quick emptying tank holding 1500 gallons, will be provided to flush the 15 inch sewer ending in manhole No. 1 area A, and two tanks of 900 gallons capacity will be put in at manholes 12 and 72, in area A, to deal with 12 inch sewers.

For 9 inch sewers, the capacity of the tanks will be from 450 to 550 gallons, according to the length of pipe and amount of sewage entering the sewer. Twenty-four essential flushing tanks will be required in Tondiarpet for 9 inch sewers.

The heads of all the 6 inch sewers will, of course, terminate in manholes, all of which will be so arranged that they may be used as flushing chambers. They will hold from 250 to about 380 gallons, according to the sewer lengths and gradients. All the essential flushing tanks of South Tondiarpet will be automatic, and independent of hand labour. They will be arranged in most cases to work about once a day, this interval as a rule being found sufficient. Wherever waste water from street fountains, etc., is found to be inadequate, a suitable tap, properly isolated from sewer gas, will be provided to augment the supply from waste.

Hand flushing from sewer heads is found to be most successful at night, when the sewer flow is small ; this may seem rather a paradox, but in actual working, the advancing body of water—rushing down the almost empty sewer—is found to exert a greater scouring effect on the invert, than would the same flush, added to a pipe perhaps already one-third full, because the inertia of the larger flow destroys the velocity of the advancing flush and causes rapid tailing out.

Ventilation.

Different systems.

99. The ventilation of sewers has been a subject of controversy and experiment for many years past in England; some few believe in no ventilation at all, advocating that all sewers be bottled up as much as possible. A second opinion is held by others, who believe in a little bottling up and a little ventilation: and it is in towns where such confused or undecided opinions are held, that one finds experiments in progress with the countless patent lamps, electric fans, "deodorizers," and chemical plants in manholes, etc.

A great body of opinion, however, has come to regard the system of tall columns and a *right* number of open street gratings, as being the most effective and practical method of ventilating sewers.

Surface inlets and tall columns proposed for Madras.

100. In Madras, the conditions of climate should prove helpful in sewer ventilation on the column and grating system, because the temperature is equable, varying slowly; the normal directions of the wind are well defined, the city is flat, and the sewer air of one district, liberated from tall columns, will not sweep over higher building areas and trouble other districts. In hilly towns this is at times a considerable difficulty.

Open grated covers will be put on the manholes where required, to act as air inlets to the sewers; the outlets will be tall columns, 6 inches in diameter and usually from 20 to 30 feet high.

Considerations which determine positions of surface inlets and of columns.

101. It has been found that in ventilating sewers nothing can be done by exact rule. The position of each column and every open grated cover must be considered and determined intelligently on its own merits. Proximity and height of houses, main directions of wind, the amounts of sunshine and shadow on each column, the levels of the ground, the paths likely to be taken by the sewer air, issuing from columns, all these must be thought of before fixing a single column or deciding the position of one tentative inlet. The inlets at road level should be put as far from houses as possible, so that they will do no harm if at times they act as outlets through adverse or unconsidered conditions; if found to be acting as an outlet the grated cover can be replaced at once by a closed cover, and a new position tried.

In Fig. 7, Plate 12, any of the manholes marked "F" are, under the conditions assumed, examples of what would be considered favourable positions for tentatively placing open grated manhole covers, those marked "V F" are very favourable, and those marked "U" would be considered unfavourable manholes for use as air inlets. The directions of two of the most important winds of Madras are shewn blowing in from the sea, and in the cross section, the crowd of arrows shews the normal course of wind when striking the buildings that face the sea. These currents will cause air *pressure* at "P," and will force air down the air inlets at "P." But, leaping over the buildings, the current of wind tends to suck air *out* of the parallel street behind the sea front, for it causes a tendency to form a vacuum at "V"; and here it would be unwise to put an inlet, because one might reasonably expect to find sewer air being sucked *out* of it, on many days. Open grated covers must not in Madras, be placed where the roadway is likely to be flooded by rainwater during the monsoon, for such water would rush straight down into the

sewer ; but where an inlet is needed in a street liable to flooding, a pipe can be brought to the closed manhole from a raised inlet fixed at the road side.

The action of ventilating columns generally overcomes or at least counterbalances any adverse conditions produced by light winds ; and when a high wind temporarily upsets some part of the normal ventilation, it must not be forgotten that there is also enormous dilution and diffusion of any gas escaping at street level on very windy days.

Mica flap inlets will be used where necessary.

In special cases mica flaps can be used to prevent occasional efflux of sewer air from inlets: but mica flaps get out of order rather easily and require frequent inspection. If in the least get-at-able, they are certain to be damaged by children and mischievous persons. They need careful placing.

Ventilating columns.

102. Ventilating columns, if high enough, require less care in placing than do inlets. The numbers of inlets and outlets required by a sewer system vary according to circumstances. Badly laid sewers, producing much gas, require more columns than do first class self-cleansing sewers. Cold climates reduce the amount of ventilation required, hot climates, however, are not believed to increase the number of columns needed, because the sun in hot countries can be depended on to heat the columns regularly and cause more rapid movement of the sewer air. Wind blowing normally across the top of a tube causes an up draught inside it ; further, if a ventilation tube is heated by the sun, the air inside it becomes lighter bulk for bulk than that outside : the lighter air is then forced up the tube by the cooler and heavier air entering beneath from the sewer. It is largely owing to these two causes, wind and temperature differences, that sewer ventilating columns do their work. In Madras, there is a hot sun by day, and more or less breeze stirring as a rule and the column system may be expected to give at least ordinary satisfaction. A normal number of columns of modern design, has been included in the estimates for Tondiarpet.

Interchangeable open and closed manhole covers.

103. All manhole cover frames for Tondiarpet, as already mentioned, (drawings 39 and 40) are designed to receive either closed or open grated covers, as may be desired : so that should an open cover be found to act as an outlet for sewer gas—instead of taking in air—then the nuisance can be promptly remedied by substituting a closed cover without disturbing the cover-frame or road in any way. This is a usual practice in some of the best drainage systems in England. In the past a common fault in ventilation has been to use far to many inlets ; sometimes every manhole cover in a sewer system has been of the open type ; in such cases covers have acted as outlets or inlets, indiscriminately, nuisance has at once arisen, and probably 75 % or more of the open covers have had to be replaced or plugged with wood, before getting satisfactory conditions. The rule for good results is an ample number of columns, and just sufficient air inlets to keep the sewers ventilated.

Defects in old type of ventilating column.

104 The value of many of the experiments made with ventilation columns is vitiated by the fact that at one time large numbers of defective columns were erected. These columns were connected to the sewers by means of plain bends leading from their feet. Dust out of the air, and scale and rust fallen from the interior of the tubes, was found to have accumulated in the

foot-bends, and this deposit was found in many cases to have partially or entirely choked up the feet of the tubes in the course of a few years. This old type of column foot is still unfortunately found in out of the way places, but the modern method is to provide an accessible pocket, to receive the falling dust and scale. Columns designed for Madras use are shewn on drawings Nos. 29 and 24.

Difference between vent pipes and ventilation pipes.

105. Before leaving the subject of sewer ventilation, the distinction should be pointed out between "vent" and "ventilation" pipes. Vent pipes are used by those few who believe in "bottling up" all sewer gas. In Madras, where the high temperature causes early decomposition of sewage and rapid formation of gas, such a system would make entry into the sewers most dangerous. In the best modern practice the object aimed at usually is to dilute sewer air thoroughly and continuously, and then liberate it well over head, where it is rapidly diffused and safely got rid of. The death rates of numerous English towns, having the column system, are a guarantee as to the innocuous results of this method of sewer ventilation. As sewer gas accumulates and increases in bottled up sewers and manholes, it must have an outlet somewhere, and it forces its way out of the vent pipes. In this way they are strictly *vents*, and not ventilators, there being no intentional currents of air set up through the sewers and manholes ; and the gas from such unventilated sewers is often highly offensive.

One inch pipes in Madras are vents.

An example of vents is afforded by the one inch pipes of Madras, which could never cause any appreciable ventilation in even a perfect sewerage system ; for their sectional area is too minute, and there are seldom less, and often more than two right angled bends in each of these one inch pipes. The loss of discharge from an air pipe, due to friction caused by sharp right angled bends, is very great ; and again, the efficacy of an air tube as a ventilator decreases rapidly as its diameter is reduced.

In the imperfect system of Madras the one inch vent pipes serve a useful purpose.

106. Yet these vent pipes it may be here mentioned, do, at present, perform what must be considered an abnormal but useful service to the defective sewers and house connections, and they should on no account be removed until the defective sewers have been remedied. Nearly every one of the sewers of Madras is surcharged during several hours of the day, often indeed permanently ; the stagnant sewage stands high up above the in-coming and out-going pipes of the manholes ; and decomposing sewage, almost stagnant, also stands often half way or more up the house drains ; it is hourly giving off concentrated gas, and where there is no one inch vent pipe, this gas forces its way through the house siphons, escapes in bubbles, and issues at road level and beside the houses. In other numerous cases, where there are no vent pipes, the imprisoned gas prevents the passage of house sewage through the siphons and down the sewer connections ; the foul liquid therefore overflows into the roads, as is illustrated in the sketch Fig. 9 Plate 12.

This direct cause of siphon overflow must not however be confused with the primary cause, which is the surcharging of the sewers. Vent pipes are not required on the house connections of a proper system of sewers. In most modern schemes, working successfully in England, vents on the ordinary house connections are quite unknown. The sewage seldom or never fills such sewers to more than $\frac{7}{8}$ of their capacity, and consequently no gas is imprisoned and compressed in

the short house drains connected to them. In Tondiarpet the sewers—if carried out as designed—will not be surcharged, no compression will take place in house drains, and no vent pipes will be put on them.

Patent methods of sewer ventilation only recommended for exceptional conditions.

107. Few if any patent methods of sewer ventilation have been a success on a large scale, and all are costly. One chemical system for example, as tried at Edinburgh, cost Rs. 105 per manhole, in alterations alone, before the apparatus could be put in. Each apparatus cost from Rs. 150 upwards; and two to four appliances were required per 1000 of population. Some of these systems have been used on a small scale for attempting to deal with especially foul and defective sewerage work, and there are sometimes cases where exceptional expense may be incurred by wealthy corporations, in order to use special means for the ventilation of sewers; as in some very important street where high buildings make the column system difficult to use, or in a case like that of the Houses of Parliament, where a specially costly system of drainage and ventilation was permissible.

Of the patent methods of sewer ventilation, the lamp column is perhaps most pushed at the present time. While single lamps are useful at particular points, where, for some special reason, it is undesirable to fix ordinary columns, yet they cannot be recommended for general use throughout the city. Experiments to determine the ventilating powers of the "Keeling gas destructor" lamp have been carried out at Bootle, Kilburn, Southampton, Reading and Croydon. They all showed that the quantity of gas extracted from the sewer was greater with the ordinary column than with the lamp column.

SECTION VIII.

Scope and Outline of Works proposed.

Scope of the Scheme.

108. The scheme of drainage for the Tondiarpet Division has been designed to work in with both the present and future drainage systems of the rest of Madras. It was found that Tondiarpet could not be considered by itself, because questions of city main drainage were too closely involved. Those problems have now been dealt with sufficiently to permit a comprehensive scheme being devised, which will include work that will be part of the future efficient drainage of the whole city, will improve the original proposals for Rayapuram and Law College Pumping Stations, and will deal effectively with the whole of North and South Tondiarpet.

Outline of General Scheme. (Drawings 1, 2, 3, & 4 and Plates 1 & 10.)

109. The Sewage from Law College Pumping Station will be pumped through the recently laid 16 inch pipes into the new 36 inch main, to be laid from Rayapuram Pumping Station. The 36 inch main will be laid along Mannarswami Covil Street for a distance of about $\frac{3}{4}$ of a mile, and will then discharge into a bell-mouth chamber to be built under the road, near the Police Station. Into the bell-mouth chamber will also be delivered the discharge from Tondiarpet, and, from this chamber, the combined sewage of Georgetown and Tondiarpet will flow down the proposed 4 ft. 6 ins. circular gravitation sewer, to the intended Sewage Farm Pumping Station, which will also receive drainage from the rest of the city. At this station, the whole of the sewage of Madras will be raised up into the Open Channel, which is to be constructed along the west side of the sewage farm, and from which sewage will be distributed over the irrigated area, through sluices.

South Tondiarpet will be divided into three drainage areas, A, B and C, each provided with its own pumping station : see drawings 3 & 4, where it will be noticed that B is the central station, A is the western, and C the eastern station.

The sewage of area A, is to be raised at once to its full height at the pumping station A, whence it will flow down-hill to station B. The sewage of area C is likewise to be raised at once to its full height at station C, so as to enable it also to flow to B. The sewers of Central South Tondiarpet—B area—will of course all drain to B. Thus the whole sewage of South Tondiarpet will arrive at B station.

This sewage arriving at B station—that is, to repeat, the whole sewage of South Tondiarpet—will be pumped up to its full height at once, to enable it to flow by gravity to the bell-mouth chamber, about 300 yards away : here it will join the Georgetown Sewage pumped up to this point from Rayapuram Station ; the two streams of sewage will unite in the chamber and will flow thence down-hill—through the 4'-6" brick sewer—to a large pumping station at the Sewage Farm.

The existing 36 inch pipes, now distributing sewage at the farm, are to be taken up and relaid to form the intended pumping main from Rayapuram to the bell-mouth chamber. To replace these 36 inch pipes, which are now too small, the Open Channel will be built.

At present, the whole of the sewage from Rayapuram and the five other existing pumping stations of Madras, is conveyed on to the farm by the old cast iron main. When the Open Channel has been built, this main will be cut and temporarily connected to the channel; the 36 inch pipes along the farm can then be taken up.

But later on, this cast iron main will be cut again at a point 550 yards nearer to Madras, and from that point the sewage will flow by gravity down a brick sewer terminating at the large farm pumping station. This last measure will improve the powers of the present pumping stations at Mylapore, Ice House Road, Langs Gardens, Napier Park and DeMellow's Road. The improvement will be caused by reducing the height they pump by 17 feet or more. The effect will be as follows :—

(1) A greater quantity can be pumped by the existing horse power.

(2) The "head" or height of water column required to force the sewage through the cast iron main will vary less than at present.

(3) A valuable provision will be made for the increase of sewage that must immediately follow the introduction of the new water-supply.

With properly arranged delivery piping, with the addition of silt pits and proper screening arrangements, and with 17 feet reduction of head the existing stations should be able to do much better work than they are doing. The quantity pumped should be increased and involuntary stoppages should become rare instead of being every day occurrences as at present.

For example I estimate that the maximum capacity of the DeMellows Road Pumping Station can be increased to three times its present capacity, by these means, and by the substitution of larger pumps for those now installed, although the same engines will be used.

The efficiency of centrifugal sewage pumps is known to be low, when they work against varying heads and heads of over about 30 or 40 feet. On the other hand, they are one of the best and cheapest pumps when dealing with low lift and constant head, and these latter conditions have been obtained in the 4 new stations which it is proposed to put down. The cast iron main, as it exists, will be too small when the new water-supply has increased the present sewage flow. The large farm station and proposed arrangements are designed to meet this fact, and to be an immediate but permanent measure towards coping with the greater sewage flow of the future.

Classification of proposed Works.

110. The works proposed and described in this report, for which designs are shown on the drawings, and for which estimates have been prepared, may be classified as.—

A. Works which are interconnected with the Drainage of Tondiarpet but are required wholly or mainly for the drainage of other districts.

B. Works which are required solely for the Drainage of Tondiarpet. All these works are shown in outline on Plate 10.

A. The works included in class A are :—

(1) The construction of an *Open Channel at the Sewage Farm* to replace the existing 36 inch, 33 inch, and 30 inch pipes. This channel will carry the whole of the Sewage of Madras along the length of the farm, and will deliver it to the irrigation channels.

(2) The *raising of the 36 inch, 33 inch and 30 inch pipes* now at the Sewage Farm.

(3) *The relaying of the 36 inch pipes*—together with such other new pipes and specials as may be required—as *a Rising Main from Rayapuram Pumping Station to the Bellmouth Chamber* at the head of the 4 feet 6 inches diameter brick sewer.

(4) The *Circular Brick Sewer*, 4 feet 6 inches in diameter, which is to carry all the sewage from Georgetown and Tondiarpet to the Pumping Station at the Sewage Farm—in future this pumping station will be referred to as the Farm Pumping Station.

(5) The *Farm Pumping Station* where the whole of the sewage of Madras, including that carried by the 4 ft. 6 ins. Sewer, will be raised into the Open Channel.

B. The works which are required solely for the Drainage of Tondiarpet include :—

(1) Raising the existing 24 inch C. I. Main from Rayapuram Station to the Farm, for partial use as a gravitation main from A to B. The Intercepting Sewers, Street Sewers, House Connections, and accessory works, for the collection of the sewage of Tondiarpet.

(2) The three Pumping Stations (A, B and C) which will deliver the sewage of South Tondiarpet into the Bellmouth Chamber at the head of the 4′—6″ Sewer.

The works which are not required solely for the drainage of Tondiarpet—class A—will be considered in the next Section ; and the works required solely for the Drainage of Tondiarpet—class B—will be described in Section X.

SECTION IX.

Works—Class A—inter-connected with the drainage of Tondiarpet, but required wholly or mainly for the drainage of other districts.

Open Channel at Sewage Farm (Drawings Nos. 5, 6, 7, 8 and 9.)

Existing pipes at Sewage Farm are inadequate.

111. The whole of the sewage, with which the pumps at the six existing stations are able to deal, is at present distributed over the farm from a pipe laid along the west side of the cultivated area. This pipe has a total length of 4,900 feet and includes the following sizes :—

36 inches diameter	3,692	ft.
33 „ „	495	„
30 „ „	713	„
Total...	4,900	ft.

It will be too small to carry the sewage when the new pumping plant at the Law College and Rayapuram Stations is working, and it will be far too small to carry the whole sewage of Madras, when the new water-supply has been introduced.

Alternatives for increasing amount of sewage which can be distributed over sewage farm.

112. The carrying capacity must therefore be increased at an early date. There are two methods by which this can be done, *viz.* :—

(1) By laying an additional pipe parallel to the existing pipe.

(2) By constructing an open channel.

If an *additional* pipe were laid, it should have a diameter of 48 inches, and when laid complete with all the necessary valves, etc., it would cost about Rs. 2,50,000 and there would still be the trouble which is experienced with the present pipe from the accumulation of silt.

An open channel, such as that shewn on the drawings, can be constructed for about Rs. 92,000, and it will liberate the existing pipes which may be used to construct nearly the whole of the new pumping main from the Rayapuram Station. After allowing for breakages and cost of raising, these pipes will be worth about Rs. 50,000 and the net cost of replacing the pipes by an open channel as proposed is therefore only about Rs. 42,000.

There will thus be a saving of about Rs. 2,08,000 by adopting an open channel in preference to a cast iron pipe.

From the point of view both of efficiency and of economy, the construction of an open channel is to be preferred greatly to the laying of an additional pipe.

Original proposals.

113. The proposals submitted by me on 26th March 1908 included the construction of an open channel at the sewage farm, and the removal of the existing 36 inch cast iron pipes for use in the new pumping main to be laid from Rayapuram Pumping Station. These proposals are now modified only as regards the design of the Open Channel.

It was proposed to construct the northern half of the channel first; because there was no doubt that, for this portion, a simple earth channel lined

with brickwork could be used with safety. But in the southern half, the top of the channel would be in places as much as 10 to 12 feet above the ground surface, and in consequence, a more elaborate design was required. As the proposals were to be submitted as soon as possible, and as the office staff was at that time very limited, the design for the southern half was left for consideration at a later date

In these circumstances the sanction of Government was accorded to the proposal for the construction of the Northen half of the open channel amongst other works in G.O. No. 1700 M., dated 14th October 1908.

Revised proposal.

114. Since then, the design ofthe Southern half has been carefully considered, and it is recommended that, where it is above ground level, the channel should be built of brickwork supported on brick piers and arches. This entails a cross section different in form from that originally proposed for the northern half, and it has been found advisable to continue the new section to the North end of the farm.

Quanity of sewage to be conveyed by the channel.

115. It will be well to give here the calculation for the quantity of sewage which the open channel will have to carry.

From the census returns, it has been estimated that the population of the areas for which provision must be made, amounted in 1901 to a total of 440,000

Adding 30 per cent. to this for future increase, *viz.* :— 132,000

The population to be provided for is then 572,000

25 gallons per head per 24 hours for this population, will give a mean dry weather flow of } 14,300,000 gallons per 24 hours =9,931 gallons per minute.

and the maximum dry weather flow, assuming $\frac{1}{2}$ to flow off in 6 hours, will be } 9,931 × 2 = 19,862 gallons per minute.

Add $\frac{1}{3}$ for rainfall. ... ... 6,621 do

Thus the maximum to be provided for will be ... ... 26,483 do

Say 26,500 gallons per minute.

Capacity of proposed channel.

116. Cross sections of the channel, which illustrate the forms of construction proposed under different conditions, are shown on Plate No. 11.

The gradient will be a uniform fall of 1 in 1000 from the South end to the North end.

The channel will carry the following quantities with the depths and velocities given below in decreasing order, *viz.* :—

Flow in gallons per minute.		Depth in feet.	Velocity in feet per second.
If Channel walls are raised in the distant future ...	43,300	3·5	5·4
Channel full	34,900	3·0	5·1
Maximum calculated flow ...	26,500	2·5	4·8
With 2 ft. of depth ...	19,200	2·0	4·4
„ 1 ft. 6 ins. of depth ...	11,900	1·5	3·8
Mean dry weather flow ...	9,900	1·3	3 5
With 1 ft. of depth ...	5,800	1·0	3·0

The sewage will thus have a self-cleansing velocity with all rates of flow which may be anticipated when the sluices at the North end only are open, and, if there should be a deposit of silt, it will be an easy matter to flush it out.

The capacity of the channel can be increased considerably if ever required, at small expense, by raising the side walls as will be described further on.

Open channel can be roofed if needed.

117. It has been observed—on many visits made during the preparation of this scheme—that sewage arrives at the farm in an advanced state of decomposition. The resulting strong smell was very noticeable on one occasion, at a point as far as one mile South of the farm.

A cause of non-freshness of sewage is to be found in the sun heated side drains and the miles of defective and half choked sewers, which permit only a slow passage of liquid to the pumps.

As a result of the new work, and future improvements in the defectively drained areas, the sewage will arrive at the farm in a fresher state, but there is still the possibility that the open channel may have to be roofed in some day, and the structure has been designed so that roofing can be added readily if required.

Possibility of Sea outfall in the future.

118. It is quite possible, that as the city grows in size, sewage farming may be found objectionable : the sound alternative would appear to be a sea outfall. In such an event, the channel sluices would be permanently closed, and a sea outfall could be constructed from the end of the channel, which is at a point about 3 miles north of the harbour. By lengthening the open channel, this distance could be increased to $3\frac{1}{2}$ miles, thereby securing an excellent point for liberating sewage into the sea.

Description of channel as designed.

119. The proposed designs for the new open channel are shown in detail on drawings 5, 6, 7, 8 & 9. which, for greater clearness, have been made to a fairly large scale. Sections of the channel are also given on Plate 2.

The southern half of the channel will be built on piers and arches, the height of the coping above ground level will be 12 feet at the South end, and will average 8 feet in the arched length. The northern half will have its "invert," or floor, at about ground level.

Measured internally the channel will be 6 feet 6 inches in width, by 3 feet deep in the middle.

Where invert is well above ground level.

Where it is above ground level, the brick channel will be carried on piers, each two feet thick and 10 feet 6 inches long, resting on wide foundations of either soorki or a special concrete. The foundation pressure on the sandy earth will not exceed half a ton per square foot, which loading should ensure absolute stability. The piers will be connected by arches 9 inches thick, each having a span of 12 feet, a rise of 2 feet, and a width of 10 feet 6 inches. There will be 146 of these arches.

Where invert is slightly above ground level.

Where the floor of the channel is slightly above ground, it will be supported on four parallel dwarf walls of either concrete or brickwork, running along under the channel, and going down into good ground. After building these low walls, the long spaces between them will be filled up with rammed and wetted

sand ; not as a permanent support, but to form a temporary centering for the concrete flooring of the channel, which will be carried permanently on the dwarf walls. This method will be efficient, and will be cheaper than taking down foundations of the whole width of the channel.

Taking the specific gravity of the brickwork at 1·8, equal to a weight of 112 lbs. per cubic foot, and assuming the channel to be brim full, then the side walls will be found to possess a factor of safety of about 3 against overturning, which factor is ample for stability, yet not wasteful of material ; the resultant of the forces will be well inside the middle third of the walls. The maximum pressure on the brickwork of the piers just above the foundations, will be about 2 tons per square foot.

Channel may be enlarged.

Should it ever be found necessary, the open channel can be enlarged readily by increasing the height and sectional area of the side walls and so giving a greater depth ; this addition to the walls is shewn by red dotted lines on drawing No. 8. In this way the capacity of the channel could be enlarged by about 62 per cent. and the altered side walls would remain stable against water pressure.

The walls of the channel (see drawing No. 8) are shewn to have an outside slope, which will be formed by stepping the bricks ; this method of building will allow the additional brickwork, if required in the future, to be added with ease, and at the same time will ensure a good bond between what will then be the old work, and the work to be added. The method of adding the new work would be similar to that which is to be used for increasing the height of the Assouan dam. The new brickwork would be bonded to the old by metal ties a narrow cavity would be left until the new work had set, and a temperature equilibrium established between the original wall and the added portion. The cavity would then be filled solid with portland cement grout, and a monolithic wall would be the result.

The sides and bottom of the channel will be rounded to promote self-cleansing, and also to give an economical section, in which the thickness of the side walls is reduced as much as possible within safe limits. The internal surface of the channel will be well plastered with Portland cement mortar, composed of three parts of sand, mixed with one part of English cement. The object of plastering is to protect the porous brickwork from atmospheric and chemical action, and also to give it a smooth watertight surface. The exterior of the channel is to be finished with soorki and chunam or stone-lime plaster.

Sluices.

Twenty or more sluices, of simple design, will be provided to liberate sewage along the length of the channel. Each sluice will work in masonry grooves and will be made of teak-wood, stiffened with an iron handle, which will work through a slotted bar built into the masonry. The bar will act as a guide and regulator for the handle, and at the same time will make it impossible for any one to steal either the wooden sluice-door or its handle. An iron pin, chained to the slotted bar, will allow each sluice to be opened as much as desired, according to the quantity of sewage to be discharged. On opening a sluice the sewage will flow down a vertical masonry shoot, formed on a pier-end of the channel, and will pass thence under the proposed farm-road to the farm irrigation channels. The continuity of the side walls is broken by the sluices, but, at each of these

points, it will be seen the wall is re-strengthened by extra brickwork, which also forms a convenient platform for the feet of the cooly operating the sluice.

Access to the sluices on the high part of the channel will be obtained by means of wrought iron ladders, well tarred, and securely built into the brickwork.

The small culverts beneath the road will have bottom and side walls of brickwork plastered with soorki and chunam, and will be covered over with granite stones.

The Corporation are in possession of a large number of granite stones, taken off defective manholes, and some of these stones will be made use of here.

120. The Channel Head has been designed to be a solidly built enlargement of the long Open Channel at its commencement. Channel Head.

It will measure internally about 25 feet in length, by 12 feet in width, and its floor will be enclosed by side walls 4 feet 9 inches high and 3 feet thick. The head, and the neck leading from it into the long channel, will be carried upon 3 arches of 8 feet 6 inches span ; the first pier will be a massive buttress containing the in-coming pipes, and forming the commencing or southern end of the Open Channel.

The Channel Head is divided into two parts, *viz.*, a Receiving Chamber (5ft. × 12ft. × 4ft. 9 ins. deep) and a Gauging Chamber (19ft. × 12ft. × 4ft. 9ins. deep) the two being separated by a "baffle-wall." The intention of the latter is to ensure that sewage in the gauging chamber shall always be quiescent, in order to enable an accurate measurement to be made of the quantity of liquid which passes over the gauging weir. From the gauging weir the sewage passes through the channel neck into the ordinary open channel, (6ft. 6ins. wide and 3 feet deep). The channel neck is carried upon an arch, the overhanging portions of which are strengthened by a re-inforcing of old steel rails.

The large pipes from the Farm Pumping Station will ascend and be enclosed inside the buttress-pier ; they will be embedded in 12 to 1 concrete, and their mouths, bellshaped, will open out in the floor of the Receiving Chamber. The pumped sewage will well up, to pass through the seven vertical openings of the baffle wall and smoothly approach the weir. Two 36 inch diameter inlet pipes will be provided, and one of these will be used to connect temporarily and as early as possible, the existing 36 inch main to the new open channel.

An 18 inch inlet pipe will be built in to provide for the future sewage of North Tondiarpet.

121. The masonry channel will terminate near the northern boundary of the farm. The open end will be fitted with chained boards working in masonry grooves ; by this arrangement the channel can be kept as full as desired ; and should it ever be necessary to discharge sewage into the sea, the boards would be removed, in whole or in part. The contingency would arise if heavy rain should flood the farm crops, and when, for any other reason, it would be inadvisable to discharge the whole of the sewage over the farm. Outlet end of channel.

An earth channel, having its sloping sides pitched with stone where it opens out from the end of the masonry channel, will convey the sewage to the sea, during such emergencies.

36 inch Pumping Main from Rayapuram Pumping Station to the head of the 4 ft. 6 in. Sewer.

Proposals accompanying letter S. E. 26-3-08.

122. The ultimate maximum quantity of sewage to be pumped from Law College and Rayapuram Pumping Stations is estimated to be 9,116 gallons per minute. In the proposals accompanying my letter S. E. No. 306, dated 26th March 1908, in order to avoid hampering future design, it was recommended that no decision should be made with regard to the main to be used between Rayapuram Pumping Station and the Sewage Farm. But for calculating the power of the pumps, it was assumed that a main 36 inches in diameter would be laid from Rayapuram Pumping Station to the Sewage Farm, and that through this main would be pumped all the sewage from Georgetown, but none from Tondiarpet.

The reason for not fixing the size at that time was the impossibility of deciding whether it would be desirable or not to include the Tondiarpet drainage in the sewage to be conveyed by the main.

Present proposals.

123. The development of the Tondiarpet Scheme has shown that the drainage of this district should, at a convenient point, join the sewage pumped from Law College and Rayapuram Pumping Stations, and the combined sewage should then flow to the Farm Pumping Station.

The main from Rayapuram Pumping Station to the point where the Tondiarpet sewage will be received, is, as now proposed, to be a pumping main 36 inches in diameter and about 4,025 feet long. From the end of this main—the point where the Tondiarpet Sewage is to join the Georgetown Sewage—a brick sewer, 4 feet 6 inches in diameter will take the combined drainage pumped from Rayapuram, Law College and the Tondiarpet Pumping Stations—the whole drainage of Georgetown and Tondiarpet—to the Farm Pumping Station. This sewer will be described further on.

36 inch pipes available.

124. For the construction of the pumping main, a length of about 3,700 feet of existing 36 inch pipes, now in use at the sewage farm, will be available as soon as the Open Channel which is to replace them, has been completed.

It is the existence of this length of 36 inch pipes which determined the size of the main to be used. Otherwise a slightly larger pipe might have been preferred to deal with the maximum flow.

This size is suitable.

125. A pipe of this size however is not unsuitable, as the following figures will show. The calculations have been made with the aid of the well known tables compiled by Santo Crimp and Bruges.

Table showing velocities and hydraulic gradients in 36 inch rising main when different quantities are pumped:—

36 inch Cast Iron Main.			Remarks.
Hydraulic gradient.	Velocity in feet per second.	Discharge in gallons per minute.	
1 in 890	3·45	9116	Maximum flow including allowance for rainwater.
1 in 1575	2·59	6834	Maximum dry weather flow.
1 in 6200	1·30	3417	Mean dry weather flow.
1 in 24800	0·65	1708	Minimum flow.

In order that there may be a self-cleansing velocity for as many hours as possible, it is desirable that the pipe should be the smallest which will take the maximum discharge, provided that the resulting velocity and head are not too great.

It will be seen from the table, that, with the maximum estimated flow, both the velocity of 3·45 feet per second, and the gradient of 1 in 890—are not excessive. Although these figures must be used to calculate the power of the engines, and the sizes of the pipes, yet they apply only to the flow contemplated when the *maximum* quantity of the sewage is combined with the total rainfall allowed for.

Beginning of 36 inch main.

126. The commencement of the proposed 36 inch main, and some of the improvements to Rayapuram Pumping Station are shewn on drawing 10*a* and 10*b*. The Rayapuram new pumps, it will be seen, are designed to discharge first into a short length of 33 inch main passing beneath Odden Paracherry Road and leading into a 33 inch Venturi Meter ; after passing through the meter, this Rayapuram sewage will join that from Law College, which arrives in a 16 inch main. The junction of the Law College and Rayapuram sewage is to be effected in a 16 into 36 inch special pipe, marked " I " on drawing No. 10 A. This junction pipe will be the true commencing point of the 36 inch main.

Railway crossing.

127. From this point the pipes will be laid forward into the Rayapuram Goods Yard of the Madras and Southern Mahratta Railway Company. Here the main will taper into and out of a 24 inch valve, and will then, on its way north, cross under 25 pairs of railway lines in a distance of about 660 feet. The pipes will need concreting for some 500 feet of the crossing, in order to protect them from fracture by the passage of engines, and, also, to protect the railway from the injury that would be caused by such a fracture.

Drawings Nos. 10 and 10*a* and 10*b* shew plans and sections of the Railway crossing, and a section of the main along Mannarsawmi Kovil Street, to where it will end opposite the Tondiarpet Police Station, in the bell-mouth chamber which will lead into the 4 feet 6 inches brick sewer.

Air valves, Hatch Boxes, and washouts.

128. An automatic air release valve will be placed on the 36 inch main where it enters the railway compound, and another will be fixed near the middle of the main. They are necessary, on this as on most pressure mains, in order to prevent the accumulation of gas or air at summits, and in long lengths of pipe.

Such accumulations give much trouble, and always seriously decrease the efficiency of the mains in which they occur.

Two hatch-boxes for internal inspection will be placed on the main; one, marked N, on drawing No. 10 A, will be at Rayapuram in order to give access to the Venturi Meter. The other will be fixed about half way between Rayapuram and the Tondiarpet bell-mouth chamber. A 12 inch washout marked "H" on drawing No. 10 A will permit the main to be emptied for inspection or repair. The outlet of the 12 inch washout will be into the old brick culvert in Odden Paracherry Road. There will be provided in addition, two 9 inch washouts in Mannarsawmi Kovil Street, South Tondiarpet; these will empty into two sewer manholes of area B, which are marked respectively 194 and 206 on drawing No. 4, which is the South Tondiarpet General Sewer Plan.

Connections at Rayapuram pumping station.

129. The new Rayapuram pumps will be installed before the 36 inch main can be completed, and until this main has been laid, they will pump into the old existing 24 inch main by means of a short 24 inch connection shewn to be made just inside the Railway compound, and marked on plan "*Temporary* 24" *connection.*" By means of this connection the new pumps will be able at once to begin discharging through the new 33 inch Venturi Meter.

The existing 24 inch stand pipe, at Rayapuram, into which three existing engines and one steam engine now pump, will be retained. The places occupied by two of the oil engines are needed for the new pumps.

The third oil engine will remain where it is, but the old steam engine along-side it will be abandoned, and its place taken by one of the displaced pair of oil engines, and there will thus remain a pair of oil engines attached to the 24 inch stand pipe which leads into the existing 24 inch main. A permanent 24 inch connection, from what will be left of the 24 inch main, will be made between this and the new 33 inch pump main; on drawing 10 A it is marked "*Permanent* 24 inch *connection.*" In this way it will always be possible to use these two oil engines as an emergency stand-bye, and their discharge will be measured through the Venturi Meter.

No stop valve is needed on this permanent 24 inch connection: for by means of their own existing valves, the oil engine pumps can each or both be cut off at will from the new system.

There is an almost complete absence of sluice valves on all the existing cast iron sewage mains of Madras. This has made the new pipe lay-out at Rayapuram a difficult problem; and has complicated the new pipe lay-outs which have already been designed for DeMellow's Road and other stations. At present, to break into the pump delivery from any one station, means the stoppage of every other sewage station in Madras. The difficulty has been closely studied in connection with the Rayapuram pipe lay-out and commencement of the 36 inch new main. Before breaking into the existing 24 inch main at Rayapuram, it will be necessary to insert a new 24 inch sluice valve on the main, at a point in North Tondiarpet some $1\frac{1}{2}$ miles from Rayapuram Station. Here, the 24 inch main will be uncovered, pumps will be got in readiness, and at a pre-arranged time, all the stations of Madras will stop pumping. The uncovered pipe must be quickly broken up, and the new sluice valve, with suitable socket-and-flange and spigot-and-flange filling pieces, will be rapidly inserted, and the joints leaded and bolted up. Before the Rayapuram end of the 36 inch main is commenced, this new 24 inch sluice valve will be closed, putting out of action the Rayapuram Station only, and permitting the work to be carried out at that station without interference with the pumping at any of the other stations.

The 4 feet 6 inches diameter Brick Sewer (Drawings 11, 12 and 13.)

General Description.

130. The whole of the ultimate sewage of South Tondiarpet, plus the whole of the sewage from Rayapuram and Law College, will be delivered into the chamber forming the top end of the 4 feet 6 inches diameter sewer.

The combined sewage—a maximum of 13,246 gallons per minute—will flow down this sewer to the large pumping station at the sewage farm. The distance from chamber to farm, that is, the length of the 4 feet 6 inches sewer, will be 5,800 feet. It will be built throughout in almost a straight line, first for a short distance along Mannarsawmy Kovil Street and then along its continuation, Narayana Chetty Street, the latter a broad and convenient road. This sewer will be close to the surface during most of its course, the average depth to invert being only eight feet.

Advantage over cast iron main.

Its greatest depth below ground will be 9 feet 6 inches, to invert, near Kuppam Road, and it has the same depth where it terminates at the Farm Pumping Station well. It should therefore be constructed cheaply, and will probably cost only 1/5 as much as the 48 inch cast pipe which would be required, if a pumping main were used instead to convey the sewage to the sewage farm.

Reasons for circular shape.

131. The circular form of sewer, 4 feet 6 inches diameter, has been adopted in preference to the well-known egg-shape. The especial object of the latter is to give good velocities with very small flows; hence it is the best form for sewers which are designed to take a large quantity of rainwater, and which therefore are nearly empty during dry weather. It is also the best form to use in districts where the population is very small, but will ultimately become great. The small quantity is concentrated in a narrow width at the bottom of the egg-shaped sewer, and flows well in consequence, because the wetted surface is small in proportion to the cross section of the flowing sewage. With a dry weather flow equal to one sixth of the maximum estimated flow, the velocity in the circular and egg-shaped sewers would be respectively 2·26 and 2·35 feet per second. As the quantity *increases* the difference *decreases*, until when the flow exceeds one-third of the carrying capacity of the sewer, the advantage of the egg-shaped section disappears, and the sewer with a circular section will then give higher velocities of flow than the egg-shaped sewer.

In the case of the 4 feet 6 inches sewer the quantity of sewage will never be small, and the sewage itself will have been screened and freed of silt before it enters the sewer; it is therefore preferable to use a circular section, not only because it is quite as efficient as the egg-shape, but because it will cost less to construct and has also an important additional advantage, as the following considerations will show.

Advantage of circular over egg-shape in this case.

132. An egg-shaped sewer, equal in discharging capacity to the 4 feet 6 inches sewer, would measure internally 5 feet 9 inches in height by 3 feet 8 inches in width. The egg-shape, therefore, would be 15 inches deeper than the 4 feet 6 inches round sewer, and for the egg-shape, 5,800 feet of trench would have to be excavated 15 inches deeper. Again, the sewage would arrive at the Farm Station, at a level 15 inches lower than if it were conveyed by the 4 feet 6 inches circular sewer. The crowns of the two forms of sewer would occupy exactly the same position throughout their length, but the invert of the egg-shape would be 15 inches below that of the circular sewer, and, in consequence, the pump lift at the large Farm Station would be increased permanently by that amount.

As regards cost then, the circular sewer has the advantage over the egg-shaped sewer in the following respects :—

(1) If the egg-shaped sewer were used, the cost of the bell-mouth chamber at the head of the sewer, and of the well at farm pumping station would be increased because they both would have to be carried deeper—involving increase in excavation and in masonry.

(2) The circular sewer is cheaper to construct because the trench it requires will be 15 inches shallower than that of the egg-shaped sewer : the quantity of the masonry is appreciably less, and the walls, being curved to a constant radius, are more easily built.

(3) The cost of pumping permanently the whole sewage of Madras an extra 15 inches in height is avoided by using a circular in preference to an egg-shaped sewer.

It is therefore better and cheaper in this case to use a 4 feet 6 inches circular sewer rather than a 5 ft. 9 ins × 3 ft. 8 ins. egg-shaped sewer.

Construction

133. If the ground is found to be very wet and sloppy, a square bottomed trench will be used, and a square concrete base put in, to receive the brick tube. (See drawing 10). But where the ground is dry, and will stand at a slope, it will be sufficient and cheaper, to excavate the trench-bottom as shown for the 36 inch main in the cross section on drawing No. 10 ; and thus save some excavation and concrete. The lower half of the sewer will be of concrete, lined with one ring of brickwork ; the upper half, above springing line, will be formed by a 9 inch semi-circular arch. Well burned platform moulded bricks will be used throughout, laid in special mortar, similar to that which is now being used on the waterworks, and which has been found to be efficient in strength, rapid in setting, unaffected by water, and much cheaper than Portland cement mortar. Collar joints of the same mortar will be made between the brick ring and concrete, and again between the two rings forming the 9 inch arch. The back of the arch will also be plastered to make it water-tight and to preserve the brickwork.

The interior of the sewer will be plastered with a mortar lining $\frac{5}{8}$ inch thick, made of 2 parts of English Portland Cement to 1 part of clean sand.

The 4′ 6″ sewer is situated throughout its length on high ground, and being quite shallow, is only capable of house-draining a narrow margin on either side of its course throughout Tondiarpet ; its true function being to convey sewage from the summit-chamber to the Farm Station.

Manholes.

134. The sewer is provided with 15 manholes and it will be noticed that some of them are over 400 feet apart, an unusual distance on street sewers, but this is a gravitation main of large size and not an ordinary sewer for receiving house drains, and more manholes are not required.

Only very seldom will inspection of this main be required, and the manholes arranged for will be sufficient for ventilation.

Ventilation.

135. The manholes, measuring internally 4′-0″ long × 2′-8″ wide, are to be formed in a simple manner, as shewn in drawing No. 13 : where it will also be seen that use will be made of granite stones taken from existing defective manholes.

The square framed ventilating type of cast iron manhole cover, 18 inch diameter (and dirt-box) shewn on drawing No. 40 will be used where needed on this sewer, and a suitable number of ventilating shafts (10) has been provided for in the estimate. Where ventilating covers are not needed, the closed covers shewn on the same drawing will be used.

The Farm Pumping Station.

136. Drawings 1 and 2 and Plate 10 shew the site, and the large drawing No. 14 gives details of the Farm Pumping Station.

Sewage arriving at the Farm Station, will be received in a chamber with a semi-circular inlet end, into which will be built the termination of the 4 ft. 6 ins. brick sewer, bringing sewage from Georgetown and Tondiarpet, and also that of the 36 ins. brick sewer bringing in sewage from the severed end of the present 33 ins. cast iron main. The inverts of these sewers at the receiving chamber will be only about 9 feet 6 inches and 7 feet respectively, below ground level. Sewage receiving chamber.

The sewage of both sewers will mingle in the semi-circular portion of the receiving chamber and will then pass forward tranquilly to the pair of silt pits.

137. The in-coming sewage will be treated very much as at any of the other stations, (see paragraphs 168—76) but the silt pits and screening arrangements will not be as large proportionally as those required at the other stations, because all the sewage from new stations will have been passed through silt pits and screens before it arrives at the Farm Station. On the other hand, the condition of the cast iron main is not known, and it may contain large quantities of silt ; again, until all the old pumping stations of Madras have been modernised and provided with silting apparatus, they will continue to pump silty and more or less unscreened sewage to the farm ; further, the lowest length of the 4 ft.-6 ins. brick sewer, on its way through North Tondiarpet, will be used as an ordinary sewer, to drain the houses for a limited width on either side of its route, and this use will bring in a certain amount of slightly silty and unscreened sewage to the Farm Station. Necessity for silt and screen pits.

138. Each silt-pit will be shut off from the receiving chamber by means of a pair of rectangular penstocks ; that is, by four penstocks in all ; two abreast giving entrance to each silt-pit, it being necessary to halve the entrances on account of their large size. The outlet ends of the silt-pits, separating them from the screening chambers, will also be fitted with a pair of exactly similar double penstocks. Duplicate silt-pits.

Each silt-pit will measure 12 feet long by 5 feet 6 inches wide. The end walls are shewn to be specially thick, and, like the mid-wall, will be reinforced to resist the water pressure when full. Each pit will be fitted with a 7 inch diameter silt-raiser of the special type designed for Madras. The 8 inch supply pipes to the silt chambers will be taken off the main pump delivery. The hand crane to raise and lower the two silt-raisers will be of larger radius than at other stations.

139. The duplicate screening pits are arranged to be exactly as at other stations, but larger. Each of the four cage pits will measure 5 feet 6 inches in width by 4 feet in length. Duplicate screening chambers.

As a rule, both screen pits, that is, all four screening cages, will be working at once ; but each pit with its pair of cages, is designed to screen singly the maximum sewage flow when passing at a speed of 3 feet per second.

As it will very seldom be necessary to empty the screen pits of sewage, it is not proposed to put penstocks on their outlet ends. But instead, suitable grooves will be formed in the masonry on each side of the openings, to give a bearing for

the ends of planks, which can then be readily inserted on the rare occasions when required ; in this way either screen pit can easily be shut off from sewage standing in the suction chamber, and the cost of four large penstocks is avoided.

Pumps.

140. *Pumping Plant :* The conditions at the Farm Pumping Station, where large volumes have to be raised to a low and constant lift, are eminently suitable for centrifugal pumps, and it is proposed to use this class of pump to lift the sewage into the Open Channel.

Engines.

141. It is however not so easy to decide on the power to drive the pumps.

First class economical steam engines are costly to instal, and a steam engine which is anything short of first class is costly in upkeep. Electrical pumping would cost considerably more than steam.

There remain oil and gas engines. The suction gas engine is undoubtedly coming to the fore, but the conditions in Madras are such as to make it doubtful whether it would be a success for this Pumping Station.

The coal usually sold in the local market is not suitable for suction gas generators and if coal of the proper description were imported, its price would be so high as to do away with the economy over other means of producing power.

Perhaps the most suitable local fuel for producing the gas, is charcoal, but the supply and uniform quality of this material is uncertain, and up to the present, the tar and other volatile substances which come over when charcoal is used, have given a great deal of trouble, and are most difficult to remove from the gas. Further, it is doubtful whether engines designed to use anthracite will work to advantage with charcoal.

There are many points which require skilled attention in using suction gas, for instance, the temperature of the complete combustion zone must be kept up to the point necessary for complete dissociation of the steam, otherwise the hydrogen constituent may vary very greatly, resulting in serious difficulty in the operation of the engines, because of the variation in the rate of combustion of the gas ; this is only one of the doubtful factors which would, in the opinion of the writer, render producer gas engines too much of an experiment to make it advisable to recommend them for use in large engines in Madras at the present time.

Oil Engines.

142. For the Farm Station, oil engines are preferable to steam engines on the ground of economy, and to suction gas engines on account of their proved reliability, and because the management of oil engines is understood in Madras.

Of oil Engines, there are two general types.

(*a*) The type which is represented in Madras by the Hornsby, Crossley, Tangye, National, Wilson and other engines.

(*b*) The Diesel type.

The Diesel type is the more expensive to instal, but it is very economical in fuel. It is however a complicated machine and liable to get out of order unless run under skilled supervision. In some cases the costs of renewals and repairs have more than counter balanced the economy in fuel, to say nothing of the loss and inconvenience resulting from stoppages. Moreover these engines have not been running in India sufficiently long to enable a correct estimate to be made of their probable life.

143. For these reasons oil engines of type (*a*) are advised for the Farm Station, and it is proposed to instal eventually eight engines of 60 B. H. P. each, to raise a total maximum of 26,500 gallons per minute to a total height of 23 feet. Six of these engines would be able to do the maximum work, and two would be kept in reserve as a stand-bye. Engines recommended.

As however it may be many years before the maximum anticipated sewage flow is obtained, it is proposed to instal now only six of the eight engines, although the engine house will be made large enough to accommodate all eight units. Six engines will be a convenient number to deal with the variations of sewage flow, for the maximum flow is estimated at $5\frac{1}{3}$ times the ordinary minimum dry weather flow. Thus the units will be able to deal economically with all variations of flow which may be anticipated. It is more important to secure these conditions in the case of the Farm Station, where large volumes have to be pumped, than for the comparatively small stations in South Tondiarpet.

144. As there are to be eventually eight engines, a single circular well is quite out of the question. Multiple wells likewise are not suitable for this station ; for they would have to be each at least 7 feet in diameter to suit the pumps, and even then they would give an insufficient storage, in proportion to the great quantity of sewage to be dealt with. A serious difficulty also arises over the necessary interconnection of multiple wells, for a large brick connecting culvert, and numerous large highly expensive penstocks and valves would be required. The provision of two, three, or four large circular wells would require an immense straggling engine house ; the screening and silting arrangements, the essential interconnection and segregation of each well, would all require an inconvenient and excessively costly station. Trough-like Suction well.

The proposed planning for the Farm Station is a trough-like form of suction-well. The eight pumps—six to be put in now and two in the future—will be mounted in a row over the centre of a brick and concrete trough, six feet wide by about $14\frac{1}{2}$ feet deep. This trough design is only suitable and economical for large stations with low suction-lift, and these will be the exact conditions at the Farm Station. After leaving the screening chambers, the sewage will at once enter this long "U" shaped channel. Cross-walls, spanning the trough and arched over the sewage flow, will be built 6 feet apart, centre to centre ; these will permit the long side walls to be of quite moderate thickness, and will also afford excellent immoveable seatings for the pumps. A pump suction will descend between every second pair of cross walls, thus fitting in with the engine spacing of 12 feet.

No foot valves will be required on the suctions. It is improbable that either the suction feet or the trough bottom will ever require examination ; but it has been thought wise to arrange for plank grooves, at intervals, so that any portion of the suction-trough can be emptied easily, if desired.

145. The pumps will discharge by easy bends into a common delivery pipe, which will be increased in size as it receives the sewage of each pump, until it is not less than 42 inches in diameter. A hand wheel sluice valve, placed on each pump delivery pipe, will allow a single pump, or any combination of pumps to work together. Main delivery.

A small air valve will be placed on each pump. Reflux valves and air vessels will not be required.

The maximum velocity in a 42 inch main delivery pipe would be nearly eight feet per second. The 42 inch pipe after leaving the engine house, will end in a breeches-piece, dividing into two 36 inch pipes, which will convey the sewage at a lower velocity, to the adjoining Open Channel. The two 36 inch pipes, on reaching the head of the Open Channel, will turn upwards, and deliver the sewage through vertical bell-mouths. The maximum velocities mentioned will not occur for many years to come, and then only at intervals. The length of double 36 inch pipes, will be laid in the strip of ground which will separate the deep excavation in wet sand for the suction-trough, from the comparatively shallow foundations of the channel head, and thereby ensure undisturbed conditions for the latter.

The engines and pumps are to be spaced 12 feet apart, centre to centre. Their suctions will be each about 16 inches, and their deliveries not less than 14 inches, in diameter. Massive concrete engine beds, incorporated with the side-wall of the suction-trough, will be provided for each engine.

The Engine house.

146. The engine house is designed to enclose all the 8 engines and pumps, and a verandah roof will cover the suction-trough. Considering the uncertainty as to how soon the seventh and eighth engines will be required, it is best to build the whole engine house at once. If this were not done, a solid temporary gable would have to be put in. The cost of this, of removing it again, of making good to the old roof, of getting a small quantity of materials and ironwork to precisely match what would be the old work,—all these expenses would counterbalance any immediate saving obtained by leaving a part of the building to be erected later on.

The completed engine house is planned to have a long central engine floor 96 feet long × 23 feet wide, a pump verandah 9 feet wide, and a front verandah of about the same width. A total area of 118 feet by 42 feet will be roofed in. There will be strong walls at the two gable ends, to steady the building and roof ; the remainder of the building will consist of stout brick piers and pillars, connected by reinforced concrete beams and brickwork filling on them. The roof will be carried by 7 steel roof trusses, each of 20 feet clear span, placed at intervals of about 12 feet over the long central engine floor ; the slope of the central roof trusses will be continued over the verandahs by means of light double angle bars, resting on the verandah pillars, and on the concrete beams connecting them. This method avoids long and expensive trusses. The roof, from the two gables, will be hipped down to end verandahs ; this will add to its appearance, and will save two steel trusses. The roofing material will be corrugated galvanised iron, of 18 B. W. G. fixed directly to light angle bar purlins. Galvanized iron sheeting, in roofs, is found to act as an efficient diagonal windbracing, and other bracing is not required. A louvred lantern will occupy the whole length of the ridge ; it is required to provide ventilation, but it will also give the roof a finished appearance.

After completion, the external surface of the roof should be well lime-washed. This very inexpensive coating preserves the ironwork, and, under the sun's rays, will make a difference of probably not less than 10 degrees in the temperature of the roof. It will require re-washing about once a year, this is the period lime-washing lasts in England, where the cost is usually under a farthing (3 pies) per square yard coated twice ; and the benefit to the ironwork, and in hot weather to the men under the roof, is very marked. In Madras, with cheaper labour, lime washing will probably cost less.

The engine house floor will be made of Cuddapah slabs laid on a foundation of cement concrete, 4 inches thick. Verandah floors will be laid with 4 inches of concrete, and are to be cement plastered. Honeycomb tiling, resting on light reinforced concrete beams, will fill the upper parts of the verandah spaces. There will be no doors, or windows, and the building should prove cheap, lasting, and cool. Tools and materials liable to be stolen will be kept in the workshops.

Cooling tanks.

147. Large cooling tanks of brickwork will be built in the compound ; the water-supply being taken to and from the engine jackets by suitable cold and hot water mains. An independent oil engine, driving a small centrifugal pump, will be provided to maintain a proper velocity in the circulating water. The hot water main should be led back under sewage working-level, *via* the suction trough, in order to take advantage of the sewage as a cooling agency.

Circular galvanised iron oil-tanks mounted on brickwork will be provided, one to supply each pair of 60 H. P. engines. These tanks will stand conveniently on the main engine house floor as shewn ; or they can be put on the front verandah. A small oil pump must be provided to fill the tanks from the oil carts.

The positions of workshops, offices, cooling-tanks and latrine, are all shewn on drawing No. 14.

Emergency overflow culvert.

148. The necessary emergency overflow from the Farm Station will be a brick culvert, starting seawards from the east side of the rectangular portion of the receiving chamber ; the outlet into the culvert will be made at a height of about 2 feet above the highest working sewage level of the chamber. See drawings 14 and 58.

The entrance to this brick culvert will be bell-mouthed. Its inlet end will be of horseshoe form, and will measure 4 ft. 6 ins. high by 4 ft. 0 ins. wide ; having bull-nosed edging inside the receiving chamber. The bell-mouth will diminish quickly into a culvert 3 ft. 10 ins. by 3 ft. 10 ins. likewise of horseshoe form in cross section and to be constructed of concrete and brickwork. The object of the bull-nosing and bell-mouth is to prevent " head of entry."

In the rare event of great overflow, the sewage can safely be allowed to rise in the receiving chamber, until its surface is 12 inches above the culvert mouth, the acquired head will then allow the maximum flow to be discharged by the culvert, which has a uniform fall of 1 in 800.

The culvert will be some 1,200 ft. long, and will terminate about 100 feet from the sea. From this point, there will be 20 feet of open pitched channel, 7 feet wide at the bottom, with sides sloped at $2\frac{1}{2}$ to 1; the short pitched channel will end with a substantial concrete curb, and the overflow, for the remaining distance, to the sea, will be carried in an open earth channel. The termination is arranged as described, in order to prevent the end of the culvert being washed away by the sea, which is undoubtedly eroding the shore of the sewage farm at a rapid rate.

A manhole on the overflow culvert (see drawing No. 58) will be provided adjoining the Farm Station compound. This chamber is shewn to be provided with masonry grooves, arranged for the easy insertion from ground level of planks, to guard against any inpouring of the sea that might be threatened during a cyclone. A similar convenient grooving, also to be worked from ground level, is shewn to be built at the sea outlet end.

An open pitched channel was designed first, to deal with the Farm Station overflow, but such a channel was found to be costlier than a brick culvert, both to construct and to maintain ; besides which, it would have cut out of use a strip of grass land about 1,200 feet long by 30 feet wide.

Arrangements for pumping North Tondiarpet. Sewage.

149. In paragraphs 183—5, the future drainage of North Tondiarpet is outlined. Particulars of future arrangements at the Farm Station for this district are suggested on drawing No. 14, where the sewage, pumped from the western half of North Tondiarpet, is shewn to enter the west side of the receiving chamber by means of a probable 18 inch pipe. See also Plate 10.

The sewage from central North Tondiarpet can gravitate to the wells of a small independent pumping station, shewn to be arranged on the multiple well system, and built adjoining the Farm Station. These wells it may be remembered, will have to be made some 8 feet deeper than the large suction-trough. Sewage from the South-East corner of North Tondiarpet (a corner which has a short sea-boundary) should also gravitate to this small independent station ; there to be pumped up separately, into the Open Channel.

The N. Tondiarpet Station will be very similar in all respects to pumping stations A, B and C for South Tondiarpet, described in paragraphs 162 to 177. This station will only be constructed after North Tondiarpet has developed sufficiently to require sewering.

SECTION X.

Works required solely for the Drainage of Tondiarpet.

South Tondiarpet be governed by three Pumping Stations, A, B and C.

150. In the scheme now put forward, South Tondiarpet has been divided into three areas, *viz.*, A, B and C, each to be drained to its own pumping station. See Drawings 1, 2, 3, and 4, and Plate No. 10.

A is the western, B the central, and C the eastern Station. On drawings 3 and 4 the boundaries of the built up area of A are shewn by a thick solid blue line, those of B are in solid red, and those of C in solid green. In addition, there are future extensions of areas A, B and C, not yet built up, and these are shewn by heavy dotted blue, red, and green lines respectively.

For example : In the case of Pumping Station A, its present built up sewerage area—enclosed by a *solid* blue line—is seen to be roughly equal to its area of future extension, which is bounded by the *dotted* blue line. Only half of area A being ready for sewering.

In " B ", which is the central of the three sewerage areas, the future extension of the sewers will be chiefly northwards and will not be great ; because area " B " is now ready for sewering almost throughout.

Still less sewer extension will be required in " C " ; for this area too, is almost wholly ripe for sewering, and but a small portion, in its extreme north, will be omitted from the sewerage scheme to be immediately put down.

Principles Governing the sewer lay-out.

151. Referring again to drawing No. 3, the main or intercepting sewers are seen to be fairly parallel to the contours ; but the mass of small street sewers run directly down hill wherever possible, and are thus "*intercepted*" by the main sewers into which they discharge. Only by following these two principles, is it possible to obtain the shallowest, cheapest, and most efficient net of sewerage pipes. In perfect conditions of ground and street lay-out, the big sewers would invariably be laid *along* the slopes, or valley sides, while the small sewers would be laid *down* the slopes, to discharge into the intercepting sewers.

The chief contours, marking the depressions and elevations of Tondiarpet, run mainly North and South. And, on examining the scheme as designed, it will be seen that the main intercepting sewers—as they should do—likewise trend largely North and South.

Road lines prevent sewers taking full advantage ground.

152. All schemes have their necessary exceptions ; where exceptions occur in this scheme the reasons for them are explained. The sewers of a city, very largely, have to follow the existing streets and roads, which usually have been laid out without reference to either contours or future drainage ; and they very frequently traverse the contours one would like them to follow for purposes of good drainage. A compromise, therefore, has always to be made between the natural drainage lines shewn by the contours, and the artificial sewer routes fixed by the roads, streets and lanes.

In the scheme of Pumping Stations A, B and C, shewn on drawing No. 3, a special crossing of the contours has been made purposely, in order to drain the largest possible area to Station B.

Sewage of A is lifted at once, and flows by gravity to B. Sewage of C is also lifted at once, and flows by gravity to B.

153. On arrival at Station A, the sewage will be raised at once to the full height required, and will then flow down hill by gravity along a 24 inch cast iron main—*via* Ramanuja Iyer Street—to the wells of Pumping Station B. The sewage arriving at Station C will similarly be at once raised, and will then flow along an 18 inch gravitation main—*via* Kalmantapam Street—until it likewise reaches the wells at Station B.

Mains A to B and C to B will be used as intercepting sewers.

On their way to B, the 24 inch iron pipe sewer from A and the 18 inch stoneware pipe sewer from C, will both be utilised as intercepting sewers; by this means, it has been possible to extend area B both east and west beyond its natural contour limits—as clearly shewn on drawing No. 3.

It will be observed that these two gravitation mains—utilised also as intercepting sewers—run at right angles to the contours, and become in consequence, the deepest sewers of the whole system. But the depth is well repaid. Every gallon of sewage they collect in the wings of B area, is saved being pumped a second time.

Sewage of A and C is re-pumped at B

For, at B Station, all the sewage of areas A, B and C is to be raised and sent on its way to the Open Channel. The sewage of districts A and C will have been pumped twice, but that of B once only, when leaving Station B; hence it is obviously an advantage to make area B as large as possible.

From B Station sewage flows by gravity to Farm Station.

154. The sewage of area B will of course drain to its own station, and Pumping Station B is to raise the whole sewage of South Tondiarpet into a brick sewer, 2 ft. 10ins. in diameter, which will convey the sewage from the Pumping Station to the bell-mouthed junction chamber to be built in Mannarsawmi Kovil Street, close to Tondiarpet Police-Station. Into this chamber will be discharged also, all the sewage from Georgetown which is pumped from the Rayapuram and Law College Stations. The combined sewage will then flow by gravity along the 4 ft. 6 ins. diameter brick sewer, (already described in paragraph 130, to 135) until it reaches the large Farm Pumping Station which is to be built at the head of the Open Channel.

Cosiderations governing choice of pumping station sites.

155. Before describing in detail the three pumping stations and their relations to the areas they drain, it will be well to state the considerations which determine the choice of sites for pumping stations, in the districts they are to drain.

A pumping station should be in such a position that the main radiating sewers will be fairly equal in length. It should be, as a rule, in or near the lowest lying part of the area, and should be so situated, that any noise, smoke, or smell, will not cause nuisance or damage.

The site should not be on land liable to be flooded at any time; it should be if possible where an emergency overflow can be obtained and the position of a station must fit in not only with the future drainage of its own area, but also with the future main drainage of the city.

Unfortunately one can seldom obtain land in precisely the most favourable position, and this factor generally, affects all the foregoing considerations more or less.

Method of selection.

A tentative position for a pumping station is first fixed on from a study of the contoured map of its district; and after making calculations for its main

intercepting sewers, from their most distant ends to the point selected. The sewer length largely determines the depth of the pump wells and brings up its own problems. There is always a position for *any* pumping station, which will give the most economical results as regards lift, and—what is generally of far greater importance in cost—will also permit the net-work of sewers and house drains to be as shallow in depth, and yet as efficient in gradient as possible. This best situation can only be determined after much work of trial and error ; the position, as found by the contours and preliminary sewer calculations must next be studied on the ground, and, if all is feasible, an actual site must then be selected. From the final point fixed on for the pumping station, the main intercepting sewers must all be re-worked out to exact sizes and gradient levels ; at this stage difficulties are sure to arise, minor shiftings of site are tried, and re-design on the trial and error method is invariably necessary to get the best results. The hundreds of street sewers have to be each separately considered and calculated for, and, of course, an exact section must be drawn of every sewer, from the largest to the smallest, and then from these, the estimates are made.

Position of pumping station governs depth of sewer net-work.

It has been thought well to give the Corporation in the above words, some idea of what has to be done in the proper selection of a single pumping station site ; irrespective of making a general Main Drainage Scheme.

The positions of the pumping stations for the three areas into which South Tondiarpet has been divided, and the main intercepting sewers of each area, will now be considered in detail.

156. Pumping Station A at first sight appears to be rather too far south in its district, but on measuring the lengths of the main sewers coming in from north and south, the site is found to be fairly well situated. The only other promising site is a little to the north-west, in the palm lands opposite the extreme western end of Ramanuja Iyer Street. But this alternative site has been known to be heavily flooded. The general conditions for fixing on a site, noted above, have of course been observed, but it should be pointed out that the very low-lying promontory of Korrukupet—projecting into the marshy area—is one cause for the rather southern position of Pumping Station A. The alternative position of Pumping Station "A" is shewn by a dotted circle, and, if difficulty were experienced in obtaining land at the first site selected, then this second site might be used : for it would make practically no alteration in the designed sewers.

Details of area and Station A.

The sewage from the eastern boundary of A (blue line area on drawings 3 & 4) will flow towards and be received, by the 12 inch and 9 inch intercepting sewers running north and south up and down the Tirruvottiyur High Road ; both these sewage flows will then turn east, at Manhole No. 63 and Manhole A. P. 9, and thence flow to Pumping Station "A."

The southern portion of area A will thus be drained by the 9 inch Tirruvottiyur High Road sewer. The projecting village of Korrukupet is also to be drained to station A by a 9 inch intercepting sewer.

North of A station, all the land slopes west, (see again Drawing No. 3 or Plate I) and the sewage as it flows westwards, from houses east of Tirruvottiyur High Road, will be intercepted by the 12 inch sewer in that road.

The remaining sewage of area A, nearly all flowing naturally westwards, will be similarly intercepted by the other main sewers running from the north to Station A.

Details of area and station C.

157. The position of Station C, from an engineer's point of view, is almost ideal, being central for its main sewers and in the lowest part of its district, which has almost a regular slope throughout towards the sea coast. (See Drawings 3 & 4 and Plate 10). One intercepting sewer runs north, and another, southwards, both fairly parallel and close to the coast. The northern main sewer branches west where it gets into flatter and wider land ; the southern sewer branches into three small intercepting sewers, in order the better to divide up its district.

The sewage of nearly all district C flows naturally eastwards, that is, towards the coast line, and thus the main sewers run north and south, to intercept it and bring it to the centrally placed pumping station.

Details of area and station B

158. A glance at Drawing No. 3 or Plate No. 10 will show that pumping station B does not occupy one of the lowest points of its district. Such a point would be found between the two lesser rolls of South Tondiarpet, say some 300 yards west of the site now fixed on. Several important advantages result from the site selected for B station. One is its proximity to the bell-mouth discharge chamber, for which the most advantageous position has been chosen : this nearness saves the necessity of six or seven hundred yards of expensive cast iron or steel rising main ; and, instead, allows a shallow and economical brick tube to be used, down which the sewage will flow by gravity to the bell-mouth chamber.

Not only is this brick sewer inexpensive to construct, but it has the further important advantage of allowing the pumps to work with an absolutely constant head, and low lift, and consequently with high efficiency.

If Pumping Station B were placed a little further West, it would be impossible to lay a gravitation sewer to the designed chamber, unless the chamber were lowered and the long 4 feet 6 inches sewer leading from it increased in both size and depth ; and then too, the large Farm Station Suction-Trough would have to be increased in depth. The Farm Station is to pump almost all the sewage of Madras, and its depth must, for economical reasons, be kept as shallow as possible. It is believed that the site chosen for B is the best possible for this scheme.

The sewer system of B area.

159. It will be noticed that, in the south-west, north-west and south-east of area B, many street sewers act as secondary or small intercepting sewers ; but one large sewer (15" diameter) runs due south down the centre of the small valley, and then branches south-east and south-west to collect sewage from the extreme corners of the district. In the north of area B, there is shewn a uniform system of secondary intercepting sewers, all flowing from North to South to be intercepted by the 24 inch cast iron gravitation main.

Certain street sewers are made 9 in diameter to get maximum extension of area B.

160. On examining drawing No. 4 it will be seen that there are half a dozen streets shewn to be sewered by 9 inch pipes (blue lines) where it would seem that 6 inch sewers might be large enough. These cases occur in the east and west

wings of area B, and result from the need for expansion of this area, as has been explained in paragraph 153. The proximity and positions of the deep A to B and C to B mains, have made it practicable to drain these half a dozen streets by sewers parallel to the contours. If 6 inch pipes were used, they would, on account of their steeper gradient, become shallow far more quickly than do the 9 inch pipes, and the wings of B would in consequence be contracted. Therefore, in order to drain the largest possible area to B, 9 inch sewers are used in these cases, for their flatter gradient gives them a much longer reach than 6 inch sewers would have. The areas served by these 9 inch sewers, are, however, not yet densely enough populated to give them a full supply of sewage, and the velocities in them might therefore at times be too small; but this difficulty will be overcome by providing at the top ends of all these rather short 9 inch sewers, efficient flushing chambers constructed to work automatically and keep these sewers well flushed

These 9 inch sewers to be flushed by automatic means.

161. There are two main sewers shewn entering the receiving chamber of Station B. On drawing No. 4 they are lettered "Main from A to B" and "Main from C to B" and they have already been referred to in para. 153. They are not ordinary sewers, but must be considered first as gravitation mains leading to B from A and C; because all the sewage of A and C will be raised into these sewers, and will then flow down them to Station B. Secondly, these two mains must be considered as important chief intercepting sewers for area B.

Mains which have dual functions.

The sewer from A, passing along Ramanuja Iyer Street, is a 24 inch cast iron pipe, and it cuts deeply through the left hand minor roll and then crosses the shallow valley to B. Starting just below ground level at A, it is at first too shallow to intercept any sewers, but, on its way eastwards, and after crossing Tirruvottiyur High Road, it becomes deep enough to begin receiving minor intercepting sewers. Then steadily increasing in depth, on its way to B, this 24 inch cast iron sewer is able to intercept nearly all the main sewers of a large area of B as they come in on each side from North and South. The 18 inch diameter sewer from C to B performs precisely similar functions, but in a lesser degree. The advantages arising from the arrangement of these 24 inch and 18 inch gravitation mains, are as follows :—

24 inch Main from A to B.

18 inch Main from C to B.

They permit the pumps of A and C to work against a constant and low lift, and consequently with high efficiency.

They become the two chief intercepting sewers of area B, on account of their necessary depth, which is thus fully utilised.

They greatly increase the acreage of area B, and diminish the areas of A and C, thus reducing the amount of sewage which has to be pumped twice, to its lowest limits.

It may be noted here, that if the sewage of A and C were to be pumped once only and forced through a pressure main to the farm, then the pumps required to deal with the resulting inconstant and high lift, would have to be of a much more costly type than those proposed; and long lengths of most expensive iron mains would be a necessity. This point has been dealt with in paragraph 34.

Disadvantage of pumping sewage through pressure mains.

Pumping Stations A, B and C.

Populations for which the pumps are designed.

162. In order to determine the quantities of sewage for which the pumps and sewers should be designed, the probable future increase in population has to be considered. Unfortunately the boundaries of Tondiarpet have been altered at every census, so that there are no accurate figures available for the increase in population which has taken place in this division, but taking Madras as a whole, and comparing the census figures for 1891 and 1901, it will be found that there was an increase of $12\frac{1}{2}$ per cent. in the 10 years. Assuming this rate of increase to continue in Tondiarpet, it will be found that, in 1912 when it may be assumed the scheme will be put into operation, the population will be as in 1901 plus 13·75 per cent., *i.e.*, 113·75 per cent. of the population of 1901. The life of the pumping plant may be taken to be 15 years and the machinery should be designed for the maximum work to be done during this term of service. That will have occurred in 1927, when, assuming the same percentage rate of increase, the population will be $113{\cdot}75 + \left(\frac{12\frac{1}{2} \times 15}{10} \times 113{\cdot}7\right) = 135$ per cent. of the population of 1901. It is for this population—35 per cent. above the census of 1901—that the pumps should be provided. The pumps are to deal with a maximum rate of sewage flow of $66\frac{2}{3}$ gallons per head per day and in addition, there will be provided at each station, a standbye capable of raising half this maximum in case of repairs, accidents, or emergencies.

The rate of $66\frac{2}{3}$ gallons per head is arrived at by assuming a sewage flow of 25 gallons per head per day, of which quantity one-half is discharged in 6 hours; this is equal to a maximum rate of dry weather flow of 50 gallons per head per day. Adding one-third as an allowance for rainwater which cannot be excluded, the figure quoted ($66\frac{2}{3}$ gallons per head per day) is obtained : this is equivalent to 46·3 gallons per minute per 1,000 inhabitants.

Population for which sewers have been designed.

163. These considerations apply to the design of the pumping machinery. The sewers have a very much longer life, and have been designed to deal with the ultimate population of South Tondiarpet. As it is impossible to forecast with certainty what that population will be, it has been necessary to make assumptions which may be considered reasonable ; these are :—

(1) That the population over the present built up areas will increase ultimately by 30 per cent. over the population of 1901.

(2) That the areas, not now built up, will eventually be populated with the same density as the built up areas in 1901, which is found to be equivalent to 120·6 persons per acre.

Adopting these methods of calculation it is found that the pumps should be able to lift the sewage of a population of 87,750 and that the sewers should be capable of dealing with an ultimate population of 110,790 although the population in 1901 was only 65,000. This does not mean that the whole of the sewers required for the larger population are to be laid at once, but only that the mains leading to the pumping stations should be of sufficient size and depth to carry the sewage

of this population. The branch street sewers, now to be laid, will be restricted to those actually required for the population served by them. But the main sewers which receive these branches, will be large enough to take the sewage from the future population of the portions at present uninhabited.

A good illustration of what is meant is afforded by area A. As shown on drawing No. 4, the northern portion of this area is as yet only sparsely populated. The main sewers, laid northwards from the pumping station, will terminate for the present at the boundary of the built up area, but they are to be laid at once of sufficient size, to take in the sewage of the expected future population of the northern unbuilt on portion of area A. Reference to the sections will show that the top ends of these sewers have been kept low enough to allow of proper gradients for the extensions anticipated.

164. The following table gives for the three areas A, B and C, the acreages, populations in 1901, estimated future populations and estimated quantities of sewage :— Details of Population and Quantities of sewage for which sewers have been designed.

Area.—	Designation of Area. A.	B.	C.	Total.
Built up area in acres	127	259	153	539
Unbuilt up area in acres	133	65	20	218
Total area in acres ...	260	324	173	757
Population.—				
Population as per Census of 1901 ...	15,316	31,233	18,451	65,000
Increase of population over built up area taken at 30%	4,594	9,370	5,536	19,500
Future population of unbuilt up areas taken as 120·6 per acre	16,040	7,839	2,412	26,291
Total population for which the sewers have been designed	35,950	48,442	26,399	110,791
Quantity of sewage.—	Gallons per minute.			
Ultimate maximum rate of sewage flow to the stations, at 46·3 gallons per minute per 1,000 of population	1,665	2,243	1,222	5,130

The following table shows the velocities and quantities of sewage dealt with, and the population served by pipe sewers of different sizes when laid at the flattest gradients proposed.

Diameter of Pipe in Inches.	Flattest Gradient proposed.	Velocity in feet per second when flowing :— Half full.	With mean dry weather flow.	Carrying capacity in gallons per minute flowing half full.	Ultimate population drained by each size of pipe, when laid at flattest gradient.
6	1 in 135	2·7	2·0	98	2,100
9	1 in 230	2·7	2·0	221	4,800
12	1 in 340	2·7	2·0	393	8,500
15	1 in 460	2·7	2·0	611	13,200
18	1 in 580	2·7	2·0	885	19,200
21	1 in 720	2·7	2·0	1,197	25,900
24	1 in 860	2·7	2·0	1,565	33,900

Populations and quantities of sewage for which the pumps have been designed.

165. The above table gives the figures used in designing the sewers. For designing the pumps, it is, as explained above, unnecessary to look forward further than 15 years from the time when the machinery will be set to work, because 15 years represents the life of this class of plant. To allow for this period, an increase in population has been assumed equal to 35 per cent. above the census returns of 1901. On this basis the following table has been prepared to show the populations and quantities of sewage with which each station will have to deal: the total lift of the sewage at each station is also given.—

	Pumping Station.			Total.
	A.	B.	C.	
Population as per Census of 1901 + 35 % ...	20,676	42,165	24,909	87,750
Maximum sewage frome ach area, in gallons per minute at 46·3 per 1,000 of population ..	957	1,952	1,153	4,062
Quantity to be lifted in gallons per minute ...	957	4,062	1,153	
Height of lift in feet	15	18	15	

Particulars of pumps provided.

166. The following is a summary of the particulars of the engines and pumps which should be provided. The engines to be oil engines using liquid fuel, and the pumps to be of centrifugal type, specially designed for sewage.

	Pumping Station.			Remarks.		
	A.	B.	C.			
Total number of units, each consisting of one engine and one pump	3	3	3	Fuel consumptions given by makers in pints per B.H.P. hour.		
No. of units for maximum work	2	2	2			
No. of standbye units	1	1	1	Load.	Fuel refined	Crude.
Maximum pumping capacity of each unit in gallons per minute...	479	2,031	576	Full.	0·75	0·74
Working head in feet...	15	18	15	¾	0·85	0·90
Sizes of pumps	8″	12″	8″	½	0·95	1·05
Pump efficiency for maximum	60 p.c.	65 p.c.	60 p.c.			
Water pump horse power	2·2	11·1	2·6	Consumption of lubricating oil approximately 0·015 pint per B. H. P. hour.		
B. H. P. to drive pump	3·7	17·1	4·3			
B. H. P. of engine using kerosine which would be required to give above B. H. P. on crude oil	5½	20·6	6			
Engines estimated for...	7½	22	7½			
Approximate No. of revolutions per minute of pump when pumping maximum quantity ...	465	350	465			

Engines and pumps.

It will be seen from the table that each station is provided with three sets of engines and pumps. Two sets are capable of dealing with the maximum sewage flow, the third being the essential standbye. The sizes of engines proposed are ample for the work to be done. There is, in fact, a considerable margin in hand, but this is always desirable in the case of a sewage pumping plant. To meet any variations of the rate of pumping which may be found necessary, each of the engines will be fitted with an arrangement whereby the speed can be regulated from 5 per cent. above, to 10 per cent. below normal, and there should be no difficulty in running the engines between these limits, if means are provided to regulate the oil supply, and if the speed is controlled by a governor.

Although the quantities of sewage to be pumped at stations A and C are not the same, yet they are sufficiently alike to justify the provision which has been made for identical engines and pumps, which provision considerably reduces the number of spare parts to be kept in stock and generally secures lower capital cost.

Gearing.

167. In preparing estimates it has been assumed that the connection between the engines and pumps will be made through a single reduction, of double helical machine cut gear, running in an oil bath. The driving wheel would be placed directly over the driven pinion ; and the whole gear would be enclosed in a strong cast iron case made in three parts and provided with self-oiling bearings.

The engine axis would be connected to the upper axis of the gear by means of a flexible coupling, and the lower axis would be connected to the pump by means of another flexible coupling.

By means of a gearing of this description a positive drive of high efficiency is obtained, and at the speed proposed it should be practically noiseless.

As compared with a belt drive, the gearing proposed is far more compact and will give less trouble. Plant fitted with it will require a smaller engine house than would belt driven pumps, but the gearing itself will be more expensive in first cost than belting. It is proposed to allow firms tendering to offer an alternative form of drive stating the overall dimensions of the buildings required ; but it will be made clear that whatever type is put forward, the pump speeds must be low. With high speeds, a smaller and therefore cheaper first cost engine can be provided, but for pumping sewage a low speed is essential, if good results are to be obtained. As a guide to the speed, the approximate number of revolutions per minute for each pump when lifting the maximum quantity of sewage, is given in the above table.

No particular make of oil engine or centrifugal pump need be specified, as there are a number of firms who supply good plant of the description required. But in any case the pumps should be provided with oiled bearings entirely separated from the stuffing boxes. The impellers and shafts should be made of bronze and should be fitted with renewable bushes designed specially for sewage. Air-pumps in duplicate will be required for charging the pumps and should be arranged so as to be run from the crankshaft of two of the engines at each station.

A reference to drawings 14 and 51 will show that the pumps are to be placed at a lower level than the engine house floors : because efficiency is increased by reducing the length of suction in the case of centrifugal pumps. and this will be done as much as possible.

Silt Pits and Silt-raisers :

Silt and screening necessary.

168. Sewage arriving at A, B & C Stations, will, on its arrival, be first freed from silt, and then screened ; all rags, sticks, leaves and large floating bodies such as cocoanuts, will be caught, and only fine floating material which will pass easily through the suctions, valves and pumps, will gain admittance into the pump wells.

General type plans. for A, B & C.

Drawing No. 52 shews the general type of arrangements to be used tor silting and screening at one of the new pumping stations. At each pumping station will be sunk three small wells, according to the types of engines and pumps adopted ; but, in any case, the same form of duplicate silting and screening pits will be adhered to.

All silt not excluded from sewers.

169. Although the use of efficient silt-pits on side drains, and of silt-catchers on house connections will both to a great extent prevent silt and sand getting into the Tondiarpet sewers, yet a certain amount is certain to find its way in, and be carried along to the pumping stations.

Even in England, where no sand is used for domestic pot scouring, a small quantity of silt is always found to arrive at the pump wells : and in Madras, a rather larger quantity may be expected. The best designed side drain silt-pits, when being cleaned out, will get their sandy contents stirred up, and a little will often be carried forward into the sewers ; in this and in similar ways, a ton or two of silt may easily be sent in a week to the pumping station of a fair sized drainage area. This silt must as far as possible, be prevented from reaching the pumps and arrangements must be provided so that it can be easily removed, raised up to ground level, and carted away.

Silt raiser.

170. An adaptation of the well-known Dortmund principle used in English sludge-press pits, was first designed for Tondiarpet Stations, but experiments were thought necessary, and were carried out at Napier Park. These shewed that ordinary methods were not applicable for raising Madras silt which is more gritty than the silt usually brought to English stations. A new apparatus has therefore been designed, and a large working model, with which a number of satisfactory trials have been made, can be seen at Napier Park. The silt-raising apparatus is to be fixed over each silt-pit, as shewn on Drawing 52 and on Plate 12. The silt raiser consists of two simple parts, one fixed, the other moveable. The fixture is a short tee-shaped pipe, of about $7\frac{3}{4}$ inches internal diameter. The moveable part is a long pipe, of 7 inches internal diameter, designed to work freely up or down inside the vertical arm of the fixed tee pipe.

On plate 12, the two pipes are separately shewn in Figs. 9 and 10, and their relative positions when at work, in Fig. 8.

The moveable inner tube is half cut away for several feet near the top, and its bottom end is provided with a specially devised inlet nozzle, to be let down into the pit bottom.

If the inner tube be moved up inside the tee tube, to the position shewn by dotted lines, and if water be forced up the inner tube—from its bottom end—that water will rise inside the inner tube until it reaches the branch of the tee piece,

when it will escape sideways ; because the inner tube is half cut away opposite this branch, and thus free escape is given to the water when it arrives at tee branch level.

Similarly, if silt and water mixed, were forced up the inner tube, the mixture would pour out of the tee branch, and if the inner tube and its nozzle were raised or lowered, it would make no difference to the free upward flow through the inner pipe and out of the tee branch, so long always as the half-cut-away portion of the inner tube were opposite the branch. In practice these conditions will be obtained whenever desired : and the silt will be raised from the pit as a thick mixture of silt and sewage.

One of these tube silt-raisers will be fixed to work over the deepest part of each silt collecting pit. Its inner tube and nozzle will be arranged to be let down into the silt, the tee piece will be fixed at the top of the silt pit and the discharge branch from it will pass through the masonry at a point about 3 feet lower down, and will deliver the mixture of silt and sewage into a small settling tank at ground level. The positions of the silt raisers and of the silt-pits are shewn in the typical drawing No. 52 already referred to, also in drawings 14 and 51, and on Plate 12.

The incoming sewers on arrival at a pumping station, [see Plate 12] will discharge directly into a semi-circular receiving chamber, from which the sewage is to be led through closable openings, into one or both of a pair of duplicate silt-pits, which will have steep sides sloping to a pump at the outgoing end. The sewage current will be slowed down as it flows across and through the silt-pits. The silt will sink down out of the sewage and accumulate in the lower part of one or both of the pits, as desired, until it needs removal. The simple hydraulic apparatus described will then be brought into use.

171. In order to empty a silt-pit of the silt caught in it, the valves at each end will first be closed, thereby shutting out the incoming sewage, and also cutting off all communication with the pump-well by way of the outlet pipe. The pit is thus converted into a narrow chamber, open only at the top, having narrow vertical sides, and a cone-shaped bottom, which has become filled with silt. All sewage will now flow to the pumps by way of the parallel duplicate silt-pit. Method of using silt raiser.

Each pit—when closed off as just described—can be readily filled right up with sewage, led to it in 8 inch pipes taken off the pump discharges. This sewage supply from the pumps will be turned on, and the closed silt-pit filled up to within about one foot of its top, submerging the tee branch to a depth of 2 feet. The imprisoned sewage can only escape from the chamber by entering the nozzle at the foot of the silt-raiser, flowing up the inner pipe and thence escaping side ways through the branch pipe of the fixed tee ; and it will begin to do so as soon as the chamber has filled up to the branch level ; but the chamber will be filled 2 feet *above* the fixed branch pipe, and thus a head of 2 feet of water will be put on to the sewage ascending the inner tube. A valve will however be fixed on the tee branch and will be kept closed until the sewage reaches the desired level.

The 2 feet of head will be sufficient to cause a rush of liquid and silt to the nozzle ; a thick mixture of silt and sewage will at once begin to ascend and flow out of the "**T**" pipe in a continuous stream, falling from its mouth into the small settling tank sunk a little in the ground. While the silt at the pit bottom is

being rapidly removed and falls towards the nozzle, the latter will be lowered as required by means of a light crane until at last only sewage will flow up; for all the silt will have been carried up from the pit into the settling tank. This tank will cause re-deposit of the raised silt, and the clarified sewage will be returned to the receiving chamber by a suitable pipe. The re-deposited silt will be drained as dry as possible, and shovelled up into carts and removed. The inner tube when out of use, will be raised above sewage level, and retained in that position by means of an iron pin thrust through small holes near the top of the tube; on lowering it an inch or two, its weight will rest on the fixed tee piece. The hand crane can then be released, and the second pit be cleaned out if desired.

This apparatus should be very useful, for it is simple, can be readily renewed or examined, has no parts to get out of order, cannot get stopped up, and should be cheap to make and simple to work. Using only one foot of head at Napier Park, it was found that not only silt and sand, but also small-fragments of brick were readily extracted out of an experimental silt-pit.

Screening Apparatus.

Screening.

172. After passing through silt-pits, the sewage will flow on through screening chambers, in order to be screened of everything that would clog up the suctions or pumps.

Mechanical power-driven sewage screens as used in England are very expensive, they require considerable space, and they all have bearings and moving parts permanently immersed in sewage, which consequently corrode rapidly, soon wear out, and are not easily or cheaply repaired. The first cost, and the upkeep of mechanical screens, would both be costlier in Madras. The great majority of mechanical sewage screens at work in England, are placed on the main outfall sewers where they arrive at sewage farm and filters, and at a level usually near or *above* ground level.

Power driven Roller Screens too cumbersome and costly.

173. The roller type of screen, consisting of a broad continuous band of copper wire or other mesh, must always, to work properly, be set at a flat angle. The bottom roller has to be fixed well below the surface of the incoming sewage, and the top roller should be above ground level, in order to deliver the caught refuse at a place from which it can be readily removed; but when the sewage surface is 14 feet or more below ground level, as it will be at Tondiarpet stations, such an inclined moving mechanical screen would have to be at least 40 feet in length to be at all effective, and even then it would not pick up cocoanuts and other round objects: they would roll back again into the screening pit.

Power driven screens not recommended.

174. The favourite mechanical screen used in England, and the only one that was thought possibly suitable for Madras, is the Stott type. In this apparatus a fixed screen is used, and is kept clean by means of moving rows of steel spikes; these travel upwards between the rows of vertical bars of the fixed screen, which is placed across the sewage flow. This type of machine has of course to be driven by power, and is always a rather elaborate and costly structure, of great weight and many moving parts. Some of the main bearings and cogs have to be immersed permanently in the sewage flow, and in consequence, the moving parts themselves have to be constantly cleaned by hand.

Screens should always be in duplicate ; that is, two power driven screens would be needed at each Madras pumping station, and the cost of any kind of power driven screen, only obtainable in England and designed really for English sewage—is prohibitive for Tondiarpet and Madras generally. After full consideration no form of power driven screen is advised.

Screening apparatus recommended.

175. The screening apparatus recommended in this report and shewn on Drawings 14, 51 and 52 has been designed to meet Madras conditions. Sewage after passing through silt pits, will flow on through duplicate chambers, each to contain a pair of light and cheap screening cages, which are to be made of half inch round bar iron, well galvanised or specially painted after construction. These cages will stand one behind the other, two in each screening chamber, and will catch all matter which is too large to pass between the bars.

Method of working.

176. When the first cage is sufficiently charged with refuse, it will be raised above the top of the chamber by means of a light hand crane, and will be swung over a cart ; the flap door forming the bottom to the cage will then be opened by releasing a catch, and the contents of the cage will drop into the cart : the interior and door of the cage, all made of smooth unbroken bars, may then, if necessary, be scraped down lightly with a rake or broom ; the door will next be slammed up and shut, and the emptied cage let down again into its original position in the sewage flow. While the first cage is being cleaned, the second, third and fourth cages will be down the pit and will be doing the work of screening.

As the screen pits are in duplicate, all 4 cages can be, and as a rule will be, in position at once ; or two only may be used, one in each pit, or two in one pit, just as desired. Any repairs or painting of cages can thus be done at leisure and with care, yet efficient screening will always go on. The four cages when screening simultaneously will be of great advantage during heavy sewage flows ; at the same time any one cage can be emptied and replaced separately, no matter what the state of flow may be.

There are, it will be noticed, two light radial hand cranes provided ; each to raise and lower the pair of cages in one screening chamber. The cranes would be mounted permanently on the chamber walls, as in the case of the single light crane for working the two silt-raisers. It may however be found cheaper to use a single crane of the derrick type, to work all the silt-raisers and screens at each station.

Summary.

To sum up, at each pumping station there will be a sewage receiving chamber, a pair of silt pits and silt-raisers, two screening pits, two pairs of screening cages, with hand crane power to work them.

Pump Suction Wells.

Multiple well system for stations A, B and C.

177. At Pumping Stations A, B & C a small separate well will be provided for each suction : thus there will be three small wells, sunk in a row, at each station. See drawing No. 51.

For the centrifugal pumps proposed to be used at all the South Tondiarpet Stations, this multiple well system has many advantages. Centrifugal pumps of whatever form, should, to obtain all possible efficiency, be placed as directly over their work, and as near the water surface as possible. If this is done, the friction of several suction bends is avoided, the suctions can be reduced to their

shortest length above water, and to their smallest diameters. To obtain these advantages in a single large well containing three suctions is very difficult, for the pumps have to be crowded together on a heavy grid of girders, which encumbers the upper part of the well.

By using the multiple system of 3 small wells in a row, as shewn on drawing No. 51, everything is greatly simplified. Each pump is fixed directly over the centre of its own well, and rests on a pair of comparatively small steel joists or girders : the well itself affording the best possible kind of foundation. The sinking of a small well, by local methods, can be done with little or no disturbance of the surrounding ground.

An excellent engine bed, solidly incorporated at one end with its well, can be obtained by this method. The estimates are based on this form of engine bed. Should belt drives be employed, then the engine beds would be some 20 feet from the wells, and the last remarks would not apply.

Each small well is seen on drawing No. 51 to be connected separately to the outlet chamber from the silt and screen pits. These connections will be made cheaply and easily by means of ordinary stoneware or iron pipes. Three cut off valves will be fixed on them in the outlet chamber, one on the mouth of each pipe connection to the wells. By means of these valves, and of the valves in the duplicate screen and silt chambers, all the sewage can be sent to a single pump, or can be divided between two, or all three pumps. Accessible suctions will not be required, for each well can at once be shut off, and emptied by means of a small inter-connected pipe attachment fixed from suction to suction. The multiple well system is cheaper than the single well system, it allows a more convenient engine room, requires a smaller compound, provides excellent pump and engine foundations, the deliveries are joined up in one easy line, and each suction well is under absolute control.

On the other hand the multiple system provides a smaller storage than does the single large well.

Engine houses.

The engine houses for A, B and C, their floors, pillars, verandahs, and galvanized iron roofs, will all be similar to the Farm Pumping Station. A brickwork curb 12 inches high will run completely round each building, being built between the verandah pillars. The object of this curb is to afford protection from exceptional rain-water flooding of the compounds. The engine floors will be little higher than the compound, and the pump floors will be several feet lower, in order to have the pumps as near as possible to the working level of the sewage in the wells.

Emergency Overflows from Sewerage Systems of South Tondiarpet.

Necessity for overflows.

178. Overflows are provided at all sewage pumping stations where they are reasonably possible. They come into operation during an unusual emergency, such as an accident disabling the engine house, breakdown or repairs to the pump main or Venturi Meter, or in the case of a sudden overwhelming rush to the pumps of water from the bursting of a large main, from the fire engines engaged at a big fire, from unusual flooding by sea or rain, or from other cause.

Should there be no overflow provided from the wells, or from the sewerage system itself, then during such emergencies the sewage is liable to overflow from the well or from the lowest open manhole covers and siphons of the system, and produce great discomfort, dangerous soiling, and, very often, serious loss and damage.

179. The lack in South Tondiarpet of natural water courses, nullahs, and ditches, added to the extreme flatness of the land—for its slight undulations are made visible only by survey and level—renders it impossible to obtain good emergency outlets from the wells of Pumping Stations A and B. Difficulty in obtaining overflow in Tondiarpet.

A number of sections specially taken, and calculations made therefrom, shewed that it was quite impracticable to get reasonable and economical emergency outlets direct from the wells of either Stations A or B. It has been found however that the essential outlets from areas A and B can be made on the sewers themselves, before they arrive at the stations. Each net-work of sewers in any one district is completely interconnected, so that if the pumps of Station A were stopped, all the sewers of A would begin filling up together, commencing of course with the lowest, and when the sewage had risen till it reached a suitable outlet from any one sewer, the whole system would get more or less relief, and the filling up would be diminished or stopped.

180. In area A, it is proposed to make three such emergency outlets from the main sewers themselves. The outlets are all three designed to discharge over the low lying palm-lands which border the west side of South Tondiarpet. This is the most practicable method of providing area A with suitable emergency overflows. Three Emergency overflows for area A.

The main outlet (see drawing 55) will be a few yards of brick culvert taken directly from Manhole No. 7 across the road and into the marsh. This outlet will deal with practically all the north and central built up area and also with part of the extension area of Station A. In the event of the pumps being overcome, the sewage instead of entering the well, will go right past it ; the flow in the 170 yards of 15 inch pipe between Pumping Station A and the outlet, will be reversed temporarily, and the sewage will flow out on to the flats where at present it finds a permanent soaking place. These overflowings however, are likely to be extremely rare, but are always provided for in good sewerage systems. First overflow.

In the future, another outlet to relieve the northern extension of area A, can be very well placed on the 12 inch sewer, some day to be laid north from Manhole No. 1 (drawing No. 4).

The second outlet for A will be a 12 inch stoneware pipe, laid directly into the marsh from Manhole No. 41. This little overflow will prevent sewage backing up in Korrukupet Village ; and in the event of a great flow to Station A, this outlet would assist the central areas by allowing reversal of flow from Manhole 7 to Manhole 41. Second overflow.

A third outlet, consisting of 170 feet of 12 inch stoneware piping, laid directly into the marsh, will be made from Manhole 102, as shewn on drawing No. 55. This overflow will relieve the southern portion of area A. The 12 inch pipes composing it are designed to have a gradient towards the sewer, for several reasons—to give easy discharge at full bore by floating the outlet flaps, to allow flushing if required, and to permit of sewage left in the outlet chamber being returned to the sewer. Third overflow.

The ends of these three outlets are to be provided with stout teak-wood flaps, to prevent flow of water into the sewers, when the flat lands get flooded.

If this happened at the time of an emergency in area A, the outlets would still be of great value, and probably of nearly their full value; for judging by inspection on the ground, the water over the flooded marsh would still be sufficiently below street level of even the lowest built up parts of area A.

Emergency overflows for area B.

181. The problem of overflows for area B has been solved by utilizing the existing open "scoop-drain," which flows down the slight central valley immediately to the south east of Pumping Station B. The nearest practical route from the pump well to the scoop drain is some 900 feet long, and even if utilised, the outlet from the well would be too high to be of much use, while the overflow channel itself would have to be a heavy and expensive masonry culvert. The tentative design which had been made was therefore abandoned, and, instead, it is proposed to make three very short and cheap sewer overflows direct into the "scoop-drain", as shewn on drawing No. 56.

First overflow

The first will be an 18 inch stoneware pipe outlet from Manhole A. P. 23, at the junction of Monegar Choultry Road with Ramanuja Iyer Street. It will be composed of about 60 feet of pipes and 20 feet of small culvert and will relieve the Central, North-western, and North-eastern portions of area B.

Second and third overflows.

A second 18 inch stoneware pipe outlet will be made from Manhole No. 137; this will relieve the eastern, and share in relieving the north-eastern portion of area B. From Manhole No. 132, a 12 inch pipe outlet will relieve the south-eastern corner of the district.

Form of flap to be employed.

These two last overflows will be respectively about 50 ft. and 20 ft. in length. Strong teak flaps, properly protected, will of course be placed on the ends of the three emergency outlets, to prevent backing up from the scoop drain. The flaps will be fixed in small chambers, and will be protected from the silt of the scoop drain by means of the small pits shewn on drawing 56. These three outlets for B are situated in the lowest part of the whole district, and should give good security against sewer and siphon overflow during unusual emergencies. The old scoop drain and its tributary side drains will ultimately be valuable assets in the surface drainage of South Tondiarpet.

Emergency oveflow of area C.

182. Pumping Station C, being close to the shore, presents no difficulties in the way of overflow, which can be made to discharge into the sea.

It is quite easy to take the overflow direct from the wells to the shore; but a survey of the pumping station site (drawing No. 57) shewed that it would be equally efficient, and more economical—because shorter—to make the overflow from Manhole C.P.2, rather than from the wells. Drawing No. 57 shews a plan and section of the proposed overflow, which will be a "U" shaped brick channel, of 20 inches radius at bottom, to be covered by Cuddapah or granite slabs.

The line of this small culvert runs due east, following the prolongation of Kalmantapam Street, and then passes beneath the existing bridge of the temporary railway. Where the channel passes under the sea defence, it will be circular in form, to give greater strength, and will terminate in a substantial head-wall, carrying a double hinged teak flap, protected by iron guard-rails, as shewn on drawing 57. It may here be remarked that all emergency outlet flaps will be hung at a very slight cant, on link-hinges. These latter ensure absolute closing, and yet offer little resistance to the out-flowing sewage.

The Farm Station overflow has already been dealt with in the description of that work.

Cutting new Roads for Sewers.

182 (*a*) A few new roads and routes for sewers will have to be acquired in parts of South Tondiarpet. One of the main sewers of A should be taken across the Roman Catholic Cemetery (see drawing No. 4) from Manhole A 140 to A 142 a distance of 115 yards. This route would not disturb any graves, there being an existing carriage way that is convenient for the line of sewer, nor will any buildings be interfered with. The cost of an easement for this route is included in the estimates.

It is proposed to take a 15 inch main sewer (green line on drawing No. 4) through the centre of a large piece of vacant land, from Manhole A 137 to Manhole A. P. 26. Four small street sewers, each crossing Monegar Choultry Road and following the natural ground slope, should be drained into this 15 inch main sewer. Each of these 4 small sewers will go across the vacant land and under the old scoop drain, in order to join the main ; each line follows the continuation of a street, and the 15 inch main follows the line of what would be a useful street. No buildings are interfered with by either the 15 inch main or the 4 tributary sewers. The length of 15 inch main in vacant ground is about 860 lineal feet, and of the 4 small sewers, respectively 350, 320, 300, and 250 feet. The 4 sewers could be rearranged if necessary; but the position proposed for the 15 inch sewer should not be altered. A portion of the 24 inch main from A to B, where it adjoins station B, must be taken for about 300 feet through private ground which is partly waste and partly garden land. No buildings are affected, and the line would be along a valuable direct route between Tiruvottiyur High Road and Monegar Choultry Road. Finally, a cut about 170 feet long from Adam Saib Street into Monegar Choultry Road would complete this route, and this last cut is, in any case, essential for the in-coming main from A to B, and for the out-going brick sewer from B to the Bell-mouth Chamber.

In area C no new roads are needed.

With the exception of the case in area A,—where the sewer goes through a cemetery, and the 170 feet. cut just mentioned—all the proposed routes for sewers coincide with what should, in my o inion, be considered street improvements ; and the cost of these proposed new public routes should not be debited against sewerage.

The total lengths of these new roads would be :—

In area A, nil—(the cemetery crossing being strictly for sewerage purposes).

In area B, 2,380 feet.

In area C, nil.

Future Drainage of North Tondiarpet.

183. Although it is not intended to drain North Tondiarpet immediately, yet the general lines of the future drainage have been considered carefully and are indicated on Plate No. 10. The dotted red lines shew what are likely to be the most

General trend of drainage.

natural and economical routes for the main intercepting sewers. The majority of the small street sewers should be laid to flow west, following the slopes of the ground as indicated by the short red arrows. An exception to this western-flowing street drainage occurs in the area south of the sewage farm, where the ground is found to slope east.

Natural Divisions of North Tondiarpet.

184. The district of North Tondiarpet divides itself, for drainage purposes, into three well marked areas which for convenience of reference may be called X, Y & Z.

"X" is the area between the railway and Tiruvottiyur High Road.

"Y" is the area between the Tiruvottiyur High Road and the Sewage Farm.

"Z" is the small area lying to the south of the Farm Station.

Area X. Of these three areas, the largest, X, can be drained to a single pumping station to be placed on the line of Ellayya Mudally Street, which skirts the western side of North Tondiarpet. From this well, which would be of moderate depth, the sewage would be lifted by pumps until it could flow by gravity to the shallow suction-trough of the Farm Pumping Station. The suggested pipe is shown on drawing No. 14.

Areas Y and Z. Areas Y and Z should drain directly towards the Farm Pumping Station. But as the levels make it quite impossible for them to drain into the shallow main suction-trough, it will be necessary to provide for them a small separate pumping station having three wells, similar in design to those recommended for South Tondiarpet. The North Tondiarpet sewage would then be pumped straight into the Open Channel by a separate short main. The position and arrangement of this small station and its incoming sewers are shewn by dotted lines on Drawing No. 14. The triple wells would have to be some 8 feet deeper than the suction-trough of the adjoining Main Farm Station. It will of course be far more economical to provide a separate well and pumps for this sewage, than to make the large suction-trough of the Farm Pumping Station deep enough to drain North Tondiarpet. The suction-trough of the Farm Station is to receive nearly all the sewage of Madras, and to lower it eight feet or even one or two feet, would entail great and unjustifiable increase in cost of plant and pumping.

Village of Pudu Vannarpet.

185. The village of Pudu Vannarpet, in North Tondiarpet, may very soon need drainage. If this occurs, as may be expected, before the rest of North Tondarpet is at all developed, then the best course will be to drain the village temporarily to a septic tank, the effluent of which may be run on to the adjacent low-lying palm lands. The sewers of Pudu Vannarpet would later on be linked up to the small station suggested. The remainder of North Tondiarpet would be left until the time came to build the western pumping station, in Ellayya Mudaly Street, as indicated on Plate No. 10.

Designs for Septic Tanks.

Designs for septic tanks, suitable for small isolated drainage areas like that of Pudu Vannarpet, and arranged for local conditions, have therefore been prepared and will be found on drawings 49 and 50.

SECTION XI.

Shone System (Drawings 59, 60 and 61).

186. As already explained, the Shone System is not recommended for Tondiarpet if the proposed gradients are adopted. If, however, it is decided that the steeper G. O. gradients must be used, then seven pumping stations will be required to deal with (the whole of the built up area of) South Tondiarpet, (plus the area which is likely to be built up within the next eighteen years).

Why Shone System is recommended if G. O. gradients are used.

For seven pumping stations, the advantages of the Shone System would be considerable as compared with separate engines, whether these were driven by steam, oil, or suction gas.

With ordinary separate engines, land would have to be acquired, and silt-pits and screening chambers constructed. None of these expenses would be incurred with the Shone ejectors, which would be placed underneath the roadways, and would raise unscreened sewage. But with the small power-units required, the efficiencies of the seven separate plants would be low and would approximate to the usual efficiency of ejector systems. The staff required to run the Shone System would be comparatively small because the ejectors act automatically. In brief, the combined cost of installing and running the ejector system for seven stations would not be high as compared with other systems, and its great convenience renders it preferable when so many small pumping stations are required.

187. The general arrangement of the system is shown on Drawing No. 59. It will be seen that there would be seven sewage lifting or "Ejector" Stations, *viz.*:— A, B, C, D, E, F and G, which drain the areas bounded by dotted green lines. These stations are supplied with compressed air from the central compressing station situated near Ejector Station B. In this station provision is made for three sets of air compressors : two to do the maximum work, the third to be a standbye. Each set is capable of raising 2,055 gallons of sewage to the required lifts.

General arrangement Drawing 59.

Central air compressing Station. Drawing 60.

The plant provided for at the compressor Station includes the following :—

3 Sets of compound non-condensing steam engines.

3 No. Galloway Boilers,—two capable of supplying steam for the maximum load.

3 No. Boiler feed-pumps.

2 No. circulating water pumps.

1 No. Feed water heater.

1 No. Steel Air Receiver 15 feet high and 4 feet diameter.

All necessary steam, air and water pipes and accessories required to make the plant complete.

188. From the central station compressed air would be supplied to the ejectors through the cast iron mains shown by yellow lines on Drawing No. 59. The sewage lifted by the ejectors would be forced through the larger cast iron mains shown by the blue lines on the same drawing, and delivered into the proposed 4 ft. 6 ins. brick sewer, which would convey the sewage to the Farm Pumping Station. Sewage from areas A, B, C, F and G would be admitted into the chamber at the

Compressed air mains and sewage rising mains.

head of the sewer. The ejectors of areas D and E respectively, would deliver into the sewer at points some 740 and 540 feet North of the chamber. The length and sizes of the cast iron pipes and compressed air mains are set out in the following table.

Route.	Cast iron pipes.			
	Sewage rising Mains.		Compressed air Mains.	
	Diameter in inches	Length in feet.	Diameter in inches.	Length in feet.
From Ejector Station G to Tiruvottiyur High Road ...	9	2,610	3	2,610
From Ejector Station F to Ramanuja Iyer Street ...	9	1,400	4	1,400
From Ejector Station A to Ramanuja Iyer Street ..	15	1,550	6	1,550
From Tiruvottiyur High Road to Monegar Choultry Road	18	2,050	7	2,050
From Ejector Station B to Ramanuja Iyer Street ...	18	1,650	7	1,650
From Ramanuja Iyer Street to chamber	21	1,920		
From Ramanuja Iyer Street to Ejector Station E ...			10	3,080
From Ejector Station C to chamber	18	2,580		
From Ejector Station D to 4′-6″ brick sewer ...	12	1,920		
From Adam Sahib Street to West side Road ...			8	1,420
From West side Road to Ejector Station C ...			7	1,350
From West side Road to Ejector Station D ...			4	1,500
Totals ...		15,680		16,610

The above two sets of iron mains are additional to the sewers required to drain the sewage to the pumping stations, and the necessity for them is one of the reasons why the Shone System is so costly. The iron rising mains may appear large for the amount of sewage which they have to carry, but the size is necessary because the Shone pumping mechanism is intermittent in action, no sewage passing whilst the ejector is being filled.

Population and quantities of sewage for which sewers are designed.

189. The planning of the sewers for the Shone System has been carried out in accordance with the G. O. gradients ; and the drainage principles, already described when dealing with the system recommended, have been embodied. For each of the seven sewerage divisions it has been assumed that the population of the built up area will increase up to 30 per cent., above what it was in 1901. It is also assumed that the present unbuilt up areas will become covered with houses until they are populated to the same density which the present built up areas had in 1901.

The following table gives for the seven areas A, B, C, D, E, F and G, the acreages, populations in 1901, estimated future populations, and estimated quantities of sewage with which the main sewers will have to deal.

Designation of area.	Area in acres.		Population.				Maximum rate of sewage flow in gallons per minute at 46·3 per 1,000 of population.
	Built up.	Not built up.	As per Census of 1901.	Anticipated increase over built up areas.	Anticipated increase over areas not built up.	Total for which sewers have been designed.	
A	97·1	24·2	11,710	3,513	2,919	18,142	838
B	145·9	—	17,596	5,279	—	22,875	1,060
C	143·2	—	17,270	5,181	—	22,451	1,042
D	53·8	29·6	6,488	1,946	3,570	12,004	556
E	28·7	50·6	3,458	1,037	6,102	10,597	490
F	39·6	47·1	4,776	1,433	5,680	11,889	551
G	30·7	66·5	3,702	1,111	8,019	12,832	593
Total...	539·0	218·0	65,000	19,500	26,290	1,10,790	5,130

Population and quantities of sewage for which ejectors have been designed.

190. For the ejectors, compressed air mains, and rising mains, the population has been taken as that in 1901 plus 35 per cent. ; and the quantity of sewage has been worked out at 25 gallons per head, half to flow off in six hours ; and to the maximum thus obtained, one third has been added for rainwater which cannot be excluded from the sewer.

On this basis the following table has been prepared :—

Designation of station.	Population.			Maximum rate of sewage flow in gallons per minute at 46·3 per 1,000 of population.
	In 1901.	35 % increase.	Total.	
A.	11,710	4,098	15,803	731·9
B.	17,596	6,159	23,755	1,099·8
C.	17,270	6,044	23,314	1,079·0
D.	6,488	2,271	8,759	405·5
E.	3,458	1,210	4,668	216·0
F.	4,776	1,672	6,448	298·5
G.	3,702	1,296	4,998	231·3
Total ...	65,000	22,750	87,750	4,062·0

Sizes of Rising Mains.

191. These figures relate to the population and quantities of sewage which may be anticipated in 1927. It may be thought that the rising mains should be designed for a longer period, in view of the fact that the pipes should certainly have a much longer life than 15 years.

This view would be undoubtedly correct, if no improvement were made in the design of the ejector system, but the writer knows of no reason why two ejectors should not be arranged in parallel, so that one is being filled whilst the other is being discharged.

If this were done, then the liquid would be forced through the mains much more uniformly than is done with the arrangement at present commonly adopted, and the pipes would then be sufficiently large to deal with a quantity nearly twice as great as that for which they are now designed.

If ejectors installed now were still serviceable at the end of 15 years, it would be only necessary to add others, having a third of the same capacity to act as a standbye ; and the powers of the plant would be approximately doubled.

Ejector Stations.

192. A typical ejector station is shown on Drawing No. 60. Two ejectors are provided, each of which is able to deal with the maximum quantity of sewage from the particular area dealt with.

The ejectors are placed in a chamber which may be situated below the roadway and to which access is obtained by means of a manhole, fitted with an iron cover.

Sometimes the chambers are made of brickwork, but in Madras, on account of the large quantity of subsoil water up to comparatively near the surface, it would be advisable to use cast iron cylinders as shown on the drawing. This opinion is borne out by experience at Bombay, where brick chambers were built when ejectors were first tried ; but brickwork was found unsatisfactory and cast iron cylinders are now employed for all new ejector chambers.

Exhaust from ejector.

193. The exhaust air may be discharged through a nozzle into a ventilating shaft, thus inducing a current of air in the sewer ; this is effective in ventilating the sewer but sometimes creates a nuisance owing to the large quantity of foul gas which is suddenly driven out into the atmosphere. To prevent this a " Filter and Silencer " is shown. The arrangement is very simple, and consists of a rectangular masonry chamber, in which a layer of coke is supported on a wooden platform or grid fixed about a foot above the bottom of the chamber : the exhaust from the ejector enters from below and passes upwards through the coke, by which it is partially purified. This chamber also acts as a reservoir to balance the pressure of the gas, with the result that the foul air passes out quietly, and comparatively slowly, in a steady stream instead of in violent puffs such as occur when no such chamber is employed.

SECTION XII.

Cost of Works Proposed.

194. In this section are given detailed estimates of the cost of the works proposed. Division of works into two classes.

As already pointed out in Section VIII, the works may be classified conveniently under two heads.

A. Works interconnected with the drainage of Tondiarpet, but required wholly or mainly for the drainage of other districts.

B. Works required solely for the drainage of Tondiarpet.

In what follows, the estimates of costs for these two classes have been kept separate.

Works classified under head "A."

195. The total estimated cost of the works included in class A is Rs. 5,20,100 as will be seen from the summary pages 120 and 121. The items which make up this sum are as follows :— Estimated cost.

		Rs.
1.	Construction of an Open Channel at Sewage Farm ...	92,000.
2.	Raising existing 36 inch cast iron pipes at Sewage Farm and relaying them—together with certain new pipes and specials required—as a rising main from Rayapuram Pumping Station to the Bell-mouth Chamber at the head of the 4 feet 6 inch sewer ...	43,400.
3.	Circular brick sewer—4 feet 6 inches diameter—to carry all the sewage from Georgetown and Tondiarpet to the Farm Pumping Station. This sewer replaces about half of the 36 inch cast iron rising main which has been sanctioned already	72,500.
4.	The Farm Pumping Station, where, eventually, the whole sewage of Madras will be lifted into the Open Channel	3,02,000.
5.	Laying a 36 inch brick gravitation main from near Paracherri Road to the Farm Station ; cutting the 33 inch cast iron main, and turning its sewage into this brick sewer	10,200.
	Total for works class A...	5,20,100.

For the first three items, certain sums have been sanctioned as shown in the following table, which also gives the amounts required in addition to those already sanctioned.

No. and Description.	Where sanctioned.	Amount sanctioned.	Amount of present Estimate.	Further amount required.
		Rs.	Rs.	Rs.
1. Open Channel at Sewage Farm a portion only sanctioned...	G.O. No. 1700 M., dated 14—10—08.	31,200	92,000	60,800
2. Laying 36 in. pumping main.	Corporation of Madras Budget, 1908–09 ...	...	43,400	—96,350 (Saving).
3. Constructing 4 ft. 6 ins. sewer.				
Amount included in Rayapuram Pumping Station (Contract M. & M. No. 3) for 36 inch main.		2,20,000	72,500	
		...	7,750	
4. Farm Pumping Station ...		*Nil.*	3,02,000	3,02,000
5. 36 in. brick gravitation main.		*Nil.*	10,200	10,200
	Totals ...	2,51,200	5,27,850	2,76,650

Sanctions required.

196. Therefore, before these works can be carried out, sanction is required for :—

1. The construction of the complete Open Channel according to the designs now submitted, at a total cost of Rs. 92,000, or an addition of Rs. 60,800 to the sum already sanctioned for *a portion* of this work.

2 & 3. The replacement of 5,800 feet of the already sanctioned 36 inch pumping main from Rayapuram Pumping Station by a 4 feet 6 inches brick sewer. It is estimated that this change will result in a saving of Rs. 96,350 over the sum already sanctioned for the 36 inch pumping main.

4. The construction of a pumping station at the Sewage Farm and the installation in this station of pumping machinery, at a total estimated cost of Rs. 3,02,000.

5. The construction of 900 feet of 36 inch brick gravitation main at an estimated cost of Rs. 10,200.

Works to be carried out first.

197. These works should be carried out in the order in which they are here set down.

The Open Channel should be constructed as soon as sanction is obtained, because it will liberate the 36 inch pipes which are required as a pumping

main from Rayapuram Pumping Station and because the existing pipes at the sewage farm are too small to take all the sewage of Madras.

The pumping main and brick sewer should be put in hand as soon as the construction of the Open Channel has liberated the necessary 36 inch pipes, because the 24 inch pipes now forming the pumping main will soon be too small to take all the sewage of Georgetown, and further, they are required for the drainage of Tondiarpet.

Works classified under head "B."

198. The total estimated cost of work required solely for the drainage of Tondiarpet is Rs. 10,45,000, as shewn in the summary pages 155 and 156. House Connections.

This includes a sum ot Rs. 1,36,400 for making house conections that is, for connecting to the sewer every house drain, from the point where it terminates at the inside face of the front wall of the house. These connections will each have an improved grating at the inlet end, a silt-catcher and siphon trap built into a masonry block, and a cleaning arm ; all of which, together with the necessary connecting pipes, have been allowed for in the estimate.

The number of puckah houses in South Tondiarpet in 1901 was only about 2,800, but I anticipate that this district will grow rapidly in the course of the next twenty years. Georgetown is already congested and will naturally overflow into Tondiarpet ; for this district, when the tramway extension has been completed, will be a most convenient residence for those who work in Georgetown. On this account provision has been made for completely sewering the present built up area and for making 4,000 house connections. Every sewer will be laid with sufficient left and right hand junctions so that house connections may be made in the future without breaking into the sewer. But no sewers will be laid until they are required, and in the meantime, for paracherries and other places where there are only temporary buildings liable to early removal, proper side drains will be constructed, and connected to the sewers by the special means described in the report. The cost of these side drains and connections will be met from the sum allowed for sewers, which the side drains will render temporarily unnecessary.

199. Provision has been made for the acquisition of all the land required for the pumping stations and for sewer easements, where new roads are not required. But nothing has been allowed for making the few new streets which are proposed (see paragraph 182*a*), because they are required for the development of the district. Acquisition of land.

200. The estimate of Rs. 10,45,000 includes the cost of main sewers for the present built up area of Tondiarpet. But these sewers are to be laid at depths sufficient to allow their extension over the whole area of South Tondiarpet, over both the built up and unbuilt up areas, which are estimated to have some day a population of 111,000, and the sizes of the mains have been selected so as to deal Cost per head.

with the sewage from this population. The small street sewers and pumping plant have been designed for a population of 87,750, and the cost of the whole scheme per head of this population is Rs. $\frac{10,45,000.}{87,750}$ = Rs. 12 per head (nearly).

Annual cost of maintenance.

201. The cost of working the Pumping Stations A, B and C will be—

		Rs.	
Cost of Establishment.—			
3 No. head drivers @ Rs. 50	...	150	per month
6 No. assistant drivers @ Rs. 30	...	180	„
9 No. coolies @ Rs. 7	...	63	„
3 No. Watchmen @ Rs. 6	...	18	„
Total per month	...	411	
		12	
Total for labour per year...		4,932	

Fuel, Oil, and Repairs.

Average B. H. P. in use, 30.

Consumption @ 1 pint per B. H. P. hour
= 30 × 24 × 365 = 2,62,800 pints per annum.

2,62,800 pints @ as. $2\frac{3}{4}$ per gallon ...	...	5,646
Lubricating oil and waste 365 days @ Rs. 3 =	...	1,095
Cost of repairs		3,000
Total cost of maintenance per year	...	14,673

Saving in cost of conservancy.

202. The Health Officer has kindly prepared a statement giving what he considers to be a moderate estimate of the saving of conservancy in Tondiarpet, which will result from the adoption of underground drainage combined with flush-out latrines and nightsoil depots.

From this statement I have compiled the table printed in the appendix page 167.

It will be seen that after making provision for a certain number of men to look after side drains, and allowing an ample number of nightsoil carts for private scavenging, there is a saving of Rs. 16,584 per annum.

This saving will be increased as water closets and flush-out latrines come into more general use, and the separate removal of nightsoil is abandoned.

Profit on Sewage Farm.

203 The working of the existing Sewage Farm shows that the pumped sewage is very valuable for growing grass crops, and a minimum profit of Rs. 10,000 per annum should be obtainable from the land which can be irrigated by the sewage from Tondiarpet.

No sum is credited to the Tondiarpet Scheme on this account but it is assumed that the extra profit of the farm would be sufficient to pay that portion of the annual charges on capital and maintenance of the Farm Pumping Station, Open Channel and 4 ft. 6 ins. sewer, which can be fairly debited to Tondiarpet ; and nothing has been charged against the Tondiarpet Scheme under those heads.

204. The annual charges to be met will be as follows :—

Total annual charges.

	Rs.
Interest and sinking fund on total estimated cost (Rs. 10,45,000) loan at 4 per cent. per annum, to be repaid in 30 years ...	60,432
Maintenance charges (paragraph 201)	14,673
Gross Total...	75,105
Deduct saving in conservancy (paragraph 202)... ...	16,584
Total net charges...	58,521

If Government make a grant of Rs. 3 lakhs.
Then the annual charges will be reduced by Rs. 17,349
and will become Rs. 58,521 less Rs. 17,349 = 41,172
In round figures Rs. 41,000

Works not included in Casses A and B, but estimated for in the Appendix.

205. There are a few works which are not included in Classes A and B, for which estimates have been prepared, and these are given in the Appendix (pages 158-167).

They include the following estimates :—

1.	Cost of draining Tondiarpet using G.O. gradients for sewers, and Shone Ejectors for raising the sewage ...	Pages	158–162
2.	Cost of Flushout Latrine ...	Page	163
3.	Cost of Nightsoil Depot ...	„	164
4.	Cost of Septic Tank ...	„	165
5.	Acquisition of land for proposed new streets...	„	166
6.	Saving in cost of conservancy in Tondiarpet through adopting underground drainage combined with flushout latrines and nightsoil depots. ...	„	167

With regard to these works :—

1. The Shone Ejector System is not recommended for the drainage of Tondiarpet, unless it should be insisted that the G.O. gradients be used.

   As will be seen, the cost of drainage on this system would be Rs. 13,74,000 or Rs. 3,29,000 in excess of the cost of the system proposed. This works out at about Rs. 16 per head of population, which is certainly not too high, for the cost of the Shone system at Bombay, Rangoon and Karachee averaged about Rs. 20 per head.

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2, 3 & 4. Nothing has been allowed for these works in estimating the cost of the drainage of Tondiarpet because it is customary to charge such works not to drainage but to "New Buildings" (*vide* current Budget Grant I—1 New Works—(*b*) Buildings items 9, 10, 19, 25, 27, 28).

5. Certain sewers are shown to be laid along lines of proposed new streets. Nothing has been allowed in the estimates for the cost of the land required, because the streets are necessary for the proper development of the districts.

But wherever sewers or pumping mains are laid through private property where roads are not now needed, a sum for the purchase of an easement has been allowed under the head of "acquisition of land."

6. The saving in conservancy in Tondiarpet through adopting underground drainage, combined with flushout latrines and nightsoil depots, has been estimated from figures supplied by the Health Officer.

A.

Detailed Estimates of cost of Works interconnected with the Drainage of Tondiarpet but required Solely or Mainly for the Drainage of other Districts.

Masonry Open Channel at Sewage Farm.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Receiving Chamber at South End of Channel.							
3,010 c.ft.	Earthwork excavation, refilling, watering, ramming, fencing, lighting, watching and removing surplus excavation	1	0	0	100 c.ft.	30	1	7
1,322 „	Concrete in cement mortar, (6 to 1)	50	0	0	„	661	0	0
572 „	Concrete (12 to 1)	31	4	0	„	178	12	0
1,115 „	Brickwork in special mortar in foundation ...	33	0	0	„	367	15	2
2,254 „	Brickwork in special mortar above ground level ...	33	0	0	„	743	13	1
654 „	Brickwork in cement mortar	45	0	0	„	294	4	10
490 „	Archwork in special mortar	35	0	0	„	171	8	0
2,283 sq.ft.	Plastering chunam	2	8	0	100 sq.ft.	57	1	2
786 „	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	„	62	14	1
520 L.ft.	Plain cornice with plaster	0	2	0	L.ft.	65	0	0
1 No.	Supplying and fixing one gun metal gauge fitted in cast iron frame with bolts, etc., complete ...	250	0	0	1 No.	250	0	0
	Rails to reinforce archwork					50	0	0
	Centerings for archwork					50	0	0
2 No.	Fixing bell mouth outlet pipes for 36″ pipes ...	5	0	0	Each.	10	0	0
						2,992	5	11
	Sundries at 5 % say ...					152	10	1
	Total carried to summary (page 120) ...					3,145	0	0

Masonry Open Channel at Sewage Farm—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Type No. 1. *Estimate for one Bay 13 feet 10½ inches long.*							
228 c.ft.	Earthwork excavation, refilling, watering and ramming, fencing, watching, lighting and removing surplus excavation	1	0	0	100 c.ft	2	4	6
76 „	Concrete in special mortar	35	0	0	„	26	9	7
307 „	Brickwork in special mortar	33	0	0	„	101	5	0
83 „	Concrete in special mortar	32	0	0	„	26	9	0
70 „	Brick-on-edge in special mortar...	33	0	0	„	23	1	7
111 L. ft.	String course with plaster	0	1	0	L.ft.	6	15	0
104 c.ft.	Archwork in special mortar	35	0	0	100 c.ft.	36	6	5
253 sq.ft.	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	20	3	10
270 „	Plastering chunam	2	8	0	„	6	12	0
						250	2	11
	Sundries at 5 % say ...					13	13	1
	Total ...					264	0	0
148 No.	Bays of 13 feet 10½ inches	264	0	0	Each.	39,072	0	0
	Total carried to summary (page 120) ...					39,080	0	0
	Type No. 2. *Estimate for a 10 feet length.*							
90 c.ft.	Earthwork excavation, refilling, watering and ramming, fencing, lighting, watching and removing surplus excavation	0	8	0	100 c.ft.	0	7	2
700 „	Earthwork embanking, excavating, laying in 1 foot layers, tamping, watering, sectioning, complete ...	0	8	0	„	3	8	0
214 „	Concrete in special mortar	35	0	0	„	74	14	5
50 „	Rammed sand filling	0	8	0	„	0	4	0
79 „	Brickwork in special mortar	33	0	0	„	26	1	1
51 „	Brick-on-edge in special mortar	33	0	0	„	16	13	3
150 sq. ft.	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	12	0	0
70 „	Plastering chunam	2	8	0	„	1	12	0
						135	11	11
	Sundries at 5 % say ...					7	4	1
	Total...					143	0	0
1,455 L.ft.	Open Channel as above	143	0	0	10 ft.	20,807	0	0
	Total carried to summary (page 120) ...					20,807	0	0

Masonry Open Channel at Sewage Farm—(Contd.)

Quantity.		Description of works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A	P.
		Type No. 3.							
		Estimate for 10 feet length.							
270	c.ft.	Earthwork, excavation, refilling, watering, ramming, fencing, lighting, watching and removing surplus excavation	0	8	0	100 c.ft	1	5	7
53	„	Earthwork embanking excavating and laying in 1 foot layers, tamping, watering and sectioning complete..	0	8	0	„	0	4	3
104	„	Concrete in special mortar	35	0	0	„	36	6	5
45	„	Brickwork in foundation in special mortar ...	33	0	0	„	14	13	7
34	„	Brickwork above ground level in special mortar ...	33	0	0	„	11	3	6
51	„	Brick-on-edge in special mortar	33	0	0	„	16	13	3
150	sq.ft.	Plastering cement $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	12	0	0
50	„	Plastering chunam	2	8	0	„	1	4	0
							94	2	7
		Sundries at 5 % say ...					5	13	5
		Total ...					100	0	0
1,343	L.ft.	Open channel as above...	100	0	0	10 L.ft.	13,430	0	0
		Total carried to summary (page 120) ..					13,430	0	0
		Oullet Chamber at North End of Open Channel including Revetment.							
746	c.ft.	Earthwork, excavation to an average depth of 3 feet 6 inches including pumping, timbering, watching fencing, lighting, refilling and removing surplus excavation...	1	0	0	100 c.ft.	7	7	4
284	„	Earthwork, embanking in 1 foot layers, tamping, watering and sectioning complete	1	0	0	„	2	13	5
100	„	Concrete in special mortar	35	0	0	„	35	0	0
161	„	Brickwork in cement mortar 2 to 1	60	0	0	„	96	9	7
23	„	Brick-on-edge in special mortar	33	0	0	„	7	9	5
		Carried over ...					149	7	9

Masonry Open Channel at sewage Farm—(Contd.)

Quantity.	Description of works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Outlet chamber at north end of open channel including revetment—(contd.)							
	Brought forward ...					149	7	9
191 sq.ft.	Plastering with cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq ft.	15	4	6
85 „	Plastering with chunam	2	8	0	„	2	2	0
295 c.ft.	Rough stone with grouting depth of stone, 12 inch on 6 inch gravel	15	0	0	100 c.ft.	44	4	0
149 „	Brick work in special mortar	33	0	0	„	49	2	9
						260	5	0
	Sundries at 5 % say ...					13	11	0
	Total carried to summary (page 120) ...					274	0	0
	Constructing Sluices.							
	Estimate for one Sluice.							
16 c.ft.	Earthwork excavation, rifilling, fencing, watching, lighting and removing surplus excavation ...	0	8	0	100 c.ft.	0	1	3
5 „	Concrete in special mortar	35	0	0	„	1	12	0
23 „	Brickwork in special mortar	33	0	0	„	10	14	3
1 „	Archwork in special mortar	35	0	0	„	0	5	7
64 sq.ft.	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	5	1	11
45 „	Plastering chunam	2	8	0	„	1	2	0
1 No.	Wrought iron work shutter with teakwood planks, etc., fixing complete as per drawing	15	0	0	1 No.	15	0	0
						34	5	0
	Sundries at 5 % say ...					1	11	0
	Total ...					36	0	0
20 No.	Sluice as above	36	0	0	Each.	720	0	0
	Total carried to summary (page 120) ...					720	0	0
	Foot-Bridge across channel.							
	Estimate for one Bridge.							
16 sq.ft.	Teakwood planks, 2½ inch thick wrought and put up.	0	9	0	Sq.ft.	9	0	0
4 No.	Holding down bolts, 1 foot 2 inches long with square head and nut and plate washer	1	8	0	Each.	6	0	0
1 „	Wrought iron ladder fixed complete	15	0	0	„	15	0	0
						30	0	0
	Sundries at 5 % say ...					2	0	0
	Total ...					32	0	0

Masonry Open Channel at Sewage Farm—(Contd.)

Quantity.	Description of Works.	Rate.			Per	Amount.		
		Rs.	A.	P.		Rs.	A.	P.
	Foot Bridge across Channel—*(Contd.)*							
	Estimate for one Bridge—(Contd.)							
20 No.	Foot-bridges and ladder as above	32	0	0	Each.	640	0	0
	Total carried to summary (page 120) ...					640	0	0
	Sewage Channels underneath proposed road.							
	Estimate for 20 Channels.							
2,000 c.ft.	Earthwork excavation, refilling, profiling, lighting, watching, removing surplus excavation	0	8	0	100 c.ft.	10	0	0
930 „	Brickwork in special mortar	33	0	0	„	306	14	5
400 „	Cut stone work in cement	2	8	0	c.ft.	1,000	0	0
1,360 sq ft.	Plastering in cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	108	12	10
80 c.ft.	Concrete in special mortar	35	0	0	100 c.ft.	28	0	0
20 No.	Connection of channels with sluice ends	10	12	0	Each.	215	0	0
						1,668	11	3
	Sundries at 5 % say ...					81	4	9
	Total carried to summary (page 120) ...					1,750	0	0
	Planting Sewage grass on side slopes of Channel.							
28,720 sq.ft.	Sowing grass on side slopes	0	2	0	100 sq.ft.	35	14	5
8 No.	Coolies for 6 months	30	0	0	Each.	240	0	0
						275	14	5
	Sundries at 5 % say ...					14	1	7
	Total carried to summary (page 120) ...					290	0	0

Masonry Open Channel at Sewage Farm—(Con'd.)

Quantity.	Description of Works.	Rate. Rs	A.	P.	Per	Amount. Rs.	A.	P.
	Road 12 feet wide along the side of Channel for a length of 5,300 L.ft.							
63,600 sq.ft.	Earthwork scraping, levelling, sectioning, tamping existing ground for laying new road	0	0	9	100 sq.ft.	29	13	0
21,200 c.ft.	Laterite metal for road	9	0	0	100 c.ft	1,908	0	0
5,300 „	Gravel for road	6	0	0	„	318	0	0
63,600 sq.ft.	Laying materials, watering, rolling, etc., complete...	0	12	0	100 sq.ft.	477	0	0
5,300 L.ft.	Making side ditches and sectioning the same along side of proposed road	0	1	0	L.ft.	331	4	0
						3064	1	0
	Sundries at 5 % say ..					153	15	0
	Total carried to summary (page 120) ...					3,218	0	0

36 inches Diameter Cast Iron Pumping Main from Rayapuram Pumping Station to Chamber at head of 4′ 6″ Brick Gravitation Sewer.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Laying 36 inch C. I. pumping main including excavation, pumping, timbering, watching, lighting, laying, jointing (with materials), refilling and removing surplus excavation :—							
600 L.ft.	5 ft. deep	3	8	0	L.ft.	2,100	0	0
2,413 „	6 ft. do	4	0	0	„	9,652	0	0
674 „	7 ft. do	4	8	0	„	3,033	0	0
150 „	8 ft. do	5	0	0	„	750	0	0
5,110 c.ft.	Concrete around pipes under Railway lines ...	35	0	0	100 c.ft.	1,788	8	0
1,000 „	Concrete around pipes in other places where required	35	0	0	„	350	0	0
3,500 L.ft.	Old C. I. pipes, 36″ dia. removed from sewage farm, loading, carting to site and unloading	0	3	0	L.ft.	656	4	0
500 „	New cast iron pipes 36″ dia. in 12 ft. length socket and spigot weight about 2 tons each delivered at side of trench	20	0	0	„	10,000	0	0
5 No.	Valve pits complete	15	0	0	Each.	75	0	0
2 No.	6″ sluice valves	48	0	0	„	96	0	0
2 No.	36″ × 9″ junction for washout	210	0	0	„	420	0	0
3 No.	9″ sluice valves	90	0	0	„	270	0	0
36 L.ft.	9″ pipes for washout	3	0	0	L.ft.	108	0	0
3 No.	Connecting washout with sewers	15	0	0	Each.	45	0	0
3 No.	9″ bends C. I.	18	0	0	„	54	0	0
36 L.ft.	Excavation, laying and jointing washout pipes ...	1	0	0	L.ft.	36	0	0
3,500 „	Restoring road surface, 7 ft. wide	0	3	0	„	656	4	0
						30,090	0	0
	Sundries 5 % say ...					1,505	0	0
	Total carried to summary (page 120) ...					Rs. 31,595	0	0
	Removing C. I. pipes 36 inches.							
4,900 L.ft.	Excavating, breaking joints, lifting, and refilling trenches for 36, 33 and 30 inches C. I. pipes at Sewage Farm	1	8	0	L.ft.	7350	0	0
	Sundries 5 % say ...					362	0	0
	Total carried to summary (page 120) ...					7,712	0	0

4 ft. 6 in. diam. Sewer from end of 36 in. Pumping Main to Farm Station—(Contd.).

Quantity.	Description of Works.	Rate.			Per	Amount.		
	One Lineal Foot of 4 ft. 6 inch Sewer.	Rs.	A.	P.		Rs.	A.	P.
75 c.ft.	Earthwork excavation to an average depth of 6 ft. including pumping, timbering, watching, fencing, lighting, refillin g removing suplus excavation ...	3	0	0	100 c.ft.	2	4	0
9 „	Arch brick work in special mortar	35	0	0	„	3	2	5
8 „	Concrete in special mortar	35	0	0	„	2	12	10
14 sq.ft.	Plastering with cement mortar, $\frac{5}{8}$ inch thick ...	8	0	0	100 sq.ft	1	1	11
27 „	Plastering with lime surki	2	8	0	„	0	10	10
1/15 No.	Junction blocks for house and sewer connections ...	...	...	.	...	0	3	6
1 L.ft.	Restoring road surface, 9 ft. wide	0	4	0	L. ft.	0	4	0
						10	7	6
	Sundries @ 5 % say ...					0	8	6
	Total for one lineal foot ...					11	0	0
5775 L.ft.	4'-6" Brick sewer as above	11	0	0	L. ft.	63,525	0	0
	Total carried to summary (page 120) ...					63,525	0	0
	Manholes on 4 ft. 6 inch Sewer from end of proposed 36 inch Pumping Main to Farm Pumping Station.							
	Estimate for one Manhole.							
	Excavation	included in sewer.						
42 c.ft.	Brickwork in special mortar	33	0	0	100 c.ft.	13	13	9
28 „	Archwork brick in special mortar	35	0	0	„	9	12	10
46 „	Concrete in special mortar	35	0	0	„	16	1	7
50 sq.ft.	Plastering in cement $\frac{5}{8}$ in. thick	8	0	0	100 sq.ft.	4	0	0
217 „	Plastering in chunam	2	8	0	„	5	6	10
8 c.ft.	Cut stone work in cement	2	8	0	c.ft.	20	0	0
5 No.	Manhole steps wrought-iron	0	12	0	each.	3	12	0
1 „	Manhole cover cast-iron complete	20	0	0	each.	20	0	0
						92	15	0
	Sundries 5 % say ...					5	1	0
	Total for one manhole ...					98	0	0
15 No.	Manholes as above	98	0	0	each.	1,470	0	0
	Total carried to summary (page 120) ...					1,470	0	0

4 ft. 6 in. diam. Sewer from end of 36 in. Pumping Main to Farm Station—(Contd.).

Quantity.	Description of Works.	Rate.			Per	Amount.		
		Rs.	A.	P.		Rs.	A.	P.
	Constructing Bell-mouth Chamber at Commencement of 4 feet 6 inches Sewer.							
1,800 c.ft.	Earthwork excavation, refilling, profiling, pumping, lighting, watching and removing surplus excavation.	3	0	0	100 c.ft.	54	0	0
300 „	Concrete 5 to 1 in cement mortar	70	0	0	100 „	210	0	0
85 „	Brickwork in special mortar	33	0	0	100 „	28	0	10
290 „	Archwork in special mortar...	35	0	0	100 „	101	8	0
7 „	Cut stone work	2	8	0	c.ft.	17	8	0
900 sq.ft.	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	72	0	0
5 No.	Iron M. H. steps	0	12	0	each.	3	12	0
1 „	Manhole cover cast iron supplying and fixing complete	20	0	0	„	20	0	0
700 sq.ft.	Restoring the road surface	3	0	0	100 sq.ft.	21	0	0
230 „	For special centerings	1	0	0	sq.ft.	230	0	0
						757	12	10
	Sundries, 5 % say ...					38	3	2
	Total carried to summary (page 120) .					796	0	0

Sewage Farm Pumping Station.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per.	Amount. Rs.	A.	P.
	Constructing Engine House.							
8,505 c.ft.	Earthwork excavation, refilling, pumping, lighting, watching, profiling, timbering, and removing surplus excavation	1	8	0	100 c.ft.	127	9	2
6,531 „	Concrete in special mortar	35	0	0	„	2,285	13	7
4,638 „	Brickwork in foundation in special mortar ...	33	0	0	„	1,530	8	8
4,179 „	Brickwork in special mortar above ground level ...	33	0	0	„	1,379	1	1
1,032 L ft.	Re-inforced concrete beams	1	0	0	L.ft.	1,032	0	0
570 sq.ft.	Honey comb work in pantiles in cement mortar, white-washing complete	7	8	0	100 sq.ft.	42	12	0
11,106 „	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	„	888	7	8
504 L.ft.	Plain cornice with $\frac{1}{4}$ brick corbel	0	4	0	L.ft.	126	0	0
608 sq.ft.	Teak door, $\frac{1}{3}$ panelled, $\frac{2}{3}$ venetianed, frames, hinges, bolts, etc., complete	1	4	0	Sq.ft.	760	0	0
7572 „	Corrugated galvanized iron roofing with bolts, nuts and washers, etc., complete	37	0	0	100 „	2,801	10	3
11,600 lbs.	Angle and Tee iron work for purlins and rafters with bolts and nuts, etc., complete	0	1	3	lb.	906	4	0
462 sq.ft.	Venetian teak fixed with frames, etc.	0	12	0	Sq.ft.	346	8	0
7. No.	Truss, wrought iron, shoes, cleats fixed bolts and nuts, etc., complete	80	0	0	Each	560	0	0
	Painting wood work, etc.				L. S.	160	0	0
						12,946	10	5
	Sundries at 5 % say...					648	5	7
	Total carried to summary (page 120) ...					13,595	0	0

Sewage Farm Pumping Station—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Constructing Suction—Trough.							
24,668 c.ft.	Earthwork excavation to an average depth of 16 feet 6 inches including pumping, timbering, watering, profiling, lighting, refilling and removing surplus excavation	10	0	0	100 c.ft.	2,466	12	10
5,980 „	Concrete in cement (2 to 1	55	0	0	„	3,289	0	0
2,000 „	Brickwork in cement mortar (2 to 1)	60	0	0	„	1,200	0	0
3,995 „	Brickwork in special mortar	33	0	0	„	1,318	5	7
848 „	Archwork brick in special mortar	35	0	0	„	296	12	10
4,904 sq.ft.	Plastering in cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	392	5	1
540 „	Flooring teak 2″ planks of 12″ broad with joists nailing complete	0	8	0	Sq. ft.	270	0	0
228 No.	Manhole steps wrought iron	0	12	0	Each	171	0	0
						9,404	4	4
	Sundries 5 % say ..					470	11	8
	Total carried to summary (page 120) ...					9,875	0	0
	Receiving and Screening Chamber.							
19,458 c.ft.	Earthwork excavation, refilling, pumping, lighting, watching, profiling, fencing, timbering and removing surplus excavation	10	0	0	100 c.ft.	1,945	12	10
2,448 „	Concrete in cement (2 to 1)	55	0	0	„	1,346	6	5
3,003 „	Brickwork in cement	60	0	0	„	1,801	12	10
3,000 „	Brickwork in special mortar	33	0	0	„	990	0	0
1,535 „	Archwork in brick in cement (2 to 1)	65	0	0	„	997	12	0
6,811 sq.ft.	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	544	14	0
450 „	Teak 2 inch plank flooring with joists, nailing, etc., complete	0	10	0	Sq.ft.	281	4	0
						7,907	14	1
	Sundries at 5 % say ...					397	1	11
	Total carried to summary (page 120) ...					8,305	0	0

Sewage Farm Pumping Station—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	All prices include delivery and fixing							
	Silt Raising Apparatus.							
	As per details on page 149					1,881	0	0
	Add for extra pipe lengths					200	0	0
	Total carried to summary (page 121)...					2,081	0	0
	Screening Apparatus.							
18 cwts.	Angle bars and fixing...	8	0	0	cwt.	144	0	0
6 No.	Cages (4 cwts. at Rs 20 per cwt.)	80	0	0	Each.	480	0	0
4 „	Screens	54	0	0	„	216	0	0
	Derrick hand crane complete					1,000	0	0
	Total carried to summary (page 121)...					1,840	0	0
	Valves, Penstocks and Delivery Pipes.							
84 ft.	36″ pipes C. I.	22	0	0	foot,	1,848	0	0
1 No.	36″ branch pipe	396	0	0	Each.	396	0	0
24 ft.	15″ pipes, C. I.	8	0	0	foot.	192	0	0
12 „	21″ do.	10	0	0	„	120	0	0
12 „	26″ do.	11	8	0	„	138	0	0
12 „	30″ do.	15	0	0	„	180	0	0
12 „	33″ do.	18	0	0	„	216	0	0
24 „	36″ do.	22	0	0	„	528	0	0
2 No.	Bell-mouth (short)	90	0	0	Each.	180	0	0
2 „	36″ bends, C. I.	142	0	0	„	284	0	0
7 „	15″ short bends, C. I....	40	0	0	„	280	0	0
60 ft.	15″ flanged pipes	6	0	0	foot.	360	0	0
6 No.	15″ wheel handle sluice valves	210	0	0	Each.	1,260	0	0
4 „	Large penstocks area 25 sq. ft. each pair, with counter-balance...	750	0	0	„	3,000	0	0
	Total carried to Summary (page 121)...					8,982	0	0

Sewage Farm Pumping Station—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Pumping Plant.							
6 Sets.	Centrifugal pumps driven by oil engines through helical gearing. Each pump to be capable of delivering 4,400 gallons per minute against a total head of 23 feet. Plant to include all suction and delivery piping inside engine house, vacuum pumps to charge suction, oil engines suitable for use with liquid fuel, fitted with exhaust pipes and foundation bolts. All fittings to make plant complete inside engine house erected and run for three months					1,84,800	0	0
1 No.	Pump pressure and sewage level recorder ...					1,600	0	0
						1,86,400	0	0
	Sundries 5% say					9,300	0	0
	Total carried to summary (page 121) ..					1,95,700	0	0
	Constructing Cooling Tank.							
9,395 c.ft.	Earthwork excavation, refilling, pumping, lighting, watching, profiling and removing surplus excavation	1	8	0	100 c.ft.	140	14	9
2,727 „	Concrete in cement	50	8	0	„	1,363	8	0
847 „	Brick-work in cement mortar	45	0	0	„	381	2	5
1,789 sq.ft.	Plastering in cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	143	1	11
70 L.ft.	4" stoneware pipe connections including all materials and labour...	1	4	0	L.ft.	87	8	0
1 No.	Gauge fixed complete					15	0	0
						2,131	3	1
	Sundries at 5 % say ...					108	12	11
	Total carried to summary (page 121) ...					2,240	0	0

Sewage Farm Pumping Station—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Office, Store and Tool Room.							
1,778 c.ft.	Earthwork, excavating, refilling, profiling, lighting, watching and removing surplus excavation ...	0	8	0	100 c.ft.	8	14	3
503 „	Concrete in special mortar	35	0	0	„	177	12	10
3,289 „	Brickwork in special mortar	33	0	0	„	1,085	5	11
42 „	Archwork in special mortar	35	0	0	„	14	11	2
3,563 sq.ft.	Plastering chunam	2	8	0	100 sq.ft.	89	1	2
432 „	Flooring, 8″×8″×2″ square brick pointed with cement, over 6″ sand	8	8	0	100 „	35	11	6
84 „	Doors teakwood-panelled with frames, hinges, bolts, etc.	1	0	0	Sq.ft.	84	0	0
45 „	Windows teak-panelled shutters, iron bars, ¾″ frames, bolts, hinges, etc., complete	1	4	0	„	56	4	0
12 c ft.	Teakwood wrought and put up	3	12	0	c.ft.	45	0	0
990 sq.ft.	Roofing Mangalore tiles, teak rafters of 3″×6″ spaced 2 feet apart with teak reepers, etc., complete.	32	0	0	100 sq.ft.	316	12	10
90 L.ft.	Eaves board, 9″×¾″ ornamental with nailing complete	0	12	0	L.ft.	67	8	0
	Painting					45	0	0
						2,027	1	8
	Sundries at 5 % say ...					102	14	4
	Total carried to summary (page 121) ...					2,130	0	0
	Latrine for Workmen and Drivers.							
481 c.ft.	Earthwork, excavation, refilling and removing surplus excavation	1	0	0	100 c.ft.	4	12	11
330 „	Concrete in special mortar	35	0	0	„	115	8	0
640 „	Brickwork in special mortar	33	0	0	„	211	3	2
132 „	Archwork in special mortar	35	0	0	„	46	3	2
1,296 sq.ft.	Plastering cement, 5/8 inch thick	8	0	0	100 sq ft.	103	10	11
16 „	Teak doors panelled with frames, hinges, bolts, etc., complete	1	0	0	Sq. ft.	16	0	0
	Carried over ...					497	6	2

Sewage Farm Pumping Station –(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Latrine for workmen and drivers (contd.)							
	Brought forward ...					497	6	2
42 sq.ft.	Honeycomb work with country pantiles and chunam mortar	7	8	0	100 sq.ft.	3	2	5
36 „	Cuddapah slabs, 2″ in cement	18	0	0	„	6	7	8
1 No.	Automatic tipping box for flushing latrine, supplying and fixing	45	0	0	Each.	45	0	0
10 L.ft.	6 inch stoneware pipes, laying, jointing, supplying materials, including earth work...	1	4	0	L.ft.	12	8	0
338 sq.ft.	Roofing with Mangalore tiles, teak reepers, rafters, nailing, rafters to be of 2″×5″ and 24″ centering, woodwork to be teak all over complete	32	0	0	100 sq.ft.	108	2	7
3 c.ft.	Teakwood wrought and put up	3	12	0	c.ft	11	4	0
26 L.ft.	Eaves board, 9″×¾″ teak	0	12	0	L.ft.	19	8	0
						703	6	10
	Sundries at 5% say ...					36	9	2
	Total carried to summary (page 121) ...					740	0	0
	Constructing Compound Wall.							
4,358 c.ft.	Earthwork, excavation and refilling to an average depth of 3 feet 6 inches including watching, profiling, lighting and removing surplus excavation ...	0	8	0	100 c.ft.	21	12	8
1,743 „	Concrete in special mortar	35	0	0	„	610	0	10
6,290 „	Brickwork in special mortar	33	0	0	„	2,075	11	2
7,788 sq.ft.	Plastering chunam	2	8	0	100 sq.ft.	194	11	2
649 L.ft.	Coping brickwork with plaster	0	3	0	L.ft.	121	11	0
2 No.	Teakwood fully battened gates including hinges, granite stone, centre guard stone, lock and key, sliding bar lock, painting, fixing complete 12 feet long by 4 feet 6 inches high	80	0	0	Each.	160	0	0
						3,183	14	10
	Sundries at 5% say ...					166	1	2
	Total carried to summary (page 121) .					3,350	0	0

Sewage Farm Pumping Station.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Emergency Overflow.							
73,000 c.ft.	Excavation in trench	3	0	0	100 c.ft.	2,190	0	0
8,000 „	Do. in open channel	2	8	0	„	200	0	0
23,200 „	Concrete in culvert and sills, &c. ...	70	0	0	„	16,240	0	0
8,300 „	Brickwork in culvert and manhole	35	0	0	„	2,905	0	0
15,200 sq. ft.	Cement plastering $\frac{5}{8}$ inch thick	8	0	0	Square	1,216	0	0
18,500 „	Chunam do.	2	8	0	„	463	0	0
480 c.ft.	Concrete in sills and head wall	70	0	0	100 c.ft.	336	0	0
166 „	Brickwork in head wall	35	0	0	„	58	0	0
12 „	24 feet. granite stone, 12″×6″	2	8	0	C.ft.	30	0	0
2 „	2″ teak planking	3	0	0	„	6	0	0
No. 4	Manhole foot irons	0	12	0	Each.	3	0	0
„ 1	Do. C. I. cover A pattern	20	0	0	„	20	0	0
680 c.ft.	Pitching in good stone not grouted	60	0	0	100 c.ft.	408	0	0
7 L.ft.	Bent rail fixed in 7 feet	2	0	0	L.ft.	14	0	0
	Allow for bellmouthing into receiving chamber and special centering					200	0	0
						24,289	0	0
	Sundries 5 % say ...					1,211	0	0
	Total carried to summary (page 121) ...					25,500	0	0

36 inch Brick Sewer from neat old Valve House to proposed Sewage Farm Pumping Station 1,550 feet long.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
90,316 c.ft.	Earthwork excavation, refilling, pumping, lighting, watching, profiling, and removing surplus excavation	3	0	0	100 c.ft.	2,709	7	8
7011 „	Archwork in special mortar	35	0	0	100 „	2,453	13	7
26,091 sq.ft.	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	2,087	4	6
4,317 c.ft.	Concrete in special mortar	35	0	0	100 c.ft.	1,510	15	2
	Manhole.							
74 c.ft.	Brickwork in special mortar	33	0	0	100 c.ft	24	6	9
53 sq.ft.	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	4	3	10
10 c.ft.	Granite stone	2	8	0	C.ft.	25	0	0
4 No.	Manhole steps	0	12	0	Each.	3	0	0
1 „	Manhole cast iron cover, 18 inches	20	0	0	„	20	0	0
						8,838	3	6
	Sundries 5 % say ...					411	12	6
	Total carried to summary (page 121) ...					9,250	0	0

Summary of Estimates for works—class A—required mainly for drainage of districts other than Tondiarpet.

From page.	Description of Works.	Amount.			Total.		
		Rs.	A.	P.	Rs.	A.	P.
	Masonry Open Channel at Sewage Farm.						
103	Receiving chamber	3,145	0	0			
104	Channel Type No. 1	39,080	0	0			
104	Do. No. 2	20,807	0	0			
105	Do. No. 3	13,430	0	0			
106	Outlet chamber	274	0	0			
106	Sluices	720	0	0			
107	Foot Bridge	640	0	0			
107	Channels under road	1,750	0	0			
107	Planting sewage grass	290	0	0			
108	Road alongside of channel	3,218	0	0			
		83,354	0	0			
	Establishment, etc., 10 % say ...	8,646	0	0	92,000	0	0
	Pumping Main.						
109	36 inch diameter cast iron main	31,595	0	0			
109	Taking up pipes at sewage farm	7,712	0	0			
		39,307	0	0			
	Establishment, etc., 10 % say ...	4,093	0	0	43,400	0	0
	4 feet 6 inches Brick Sewer.						
110	Sewer	63,525	0	0			
110	Manholes	1,470	0	0			
111	Bell-mouth chamber	796	0	0			
		65,791	0	0			
	Establishment, etc., 10 % say ...	6,709	0	0	72,500	0	0
	Sewage Farm Pumping Station.						
112	Engine house	13,595	0	0			
113	Suction trough	9,875	0	0			
113	Receiving and screening chamber	8,305	0	0			
	Carried over ...	31,775	0	0	2,07,900	0	0

Summary of Estimates for works—class A—required mainly for drainage of districts other than Tondiarpet—(Contd.)

From page.	Description of Works.	Amount.			Total.		
	Sewage Farm Pumping Station—(Contd.)	Rs.	A.	P.	Rs.	A.	P.
	Brought forward ...	31,775	0	0	2,07,900	0	0
114	Silt raisers etc.	2,081	0	0			
114	Screening apparatus	1,840	0	0			
114	Valves, penstocks and pump delivery pipes	8,982	0	0			
115	Pumping machinery	1,95,700	0	0			
115	Cooling tank	2,240	0	0			
116	Office store and tool rooms	2,130	0	0			
117	Latrine	740	0	0			
117	Compound wall	3,350	0	0			
118	Constructing emergency overflow	25,500	0	0			
		2,74,338	0	0			
	Add for establishment, etc., 10 % say ...	27,662	0	0	3,02,000	0	0
119	36 inch brick sewer	9,250	0	0			
	Add for establishment 10 % say ...	950	0	0	10,200	0	0
	Grand total of estimated cost of works class A ...				5,20,100	0	0

B.

Detailed Estimates of Cost of Works required solely for the Drainage of South Tondiarpet.

Pipe Sewers.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	6 inch Sewers.							
	6 inches internal diameter best English stoneware pipes laid complete, including excavation, pumping, timbering, laying, jointing and refilling :—							
19,430 L. ft.	3 feet deep to invert	1	0	0	L.ft.	19,430	0	0
35,610 „	4 „ „	1	1	0	do	37,835	10	0
18,320 „	5 „ „	1	2	0	do	20,610	0	0
11,620 „	6 „ „	1	15	0	do	22,513	12	0
7,990 „	7 „ „	2	3	0	do	17,478	2	0
5,140 „	8 „ „	2	6	0	do	12,207	8	0
2,620 „	9 „ „	2	10	0	do	6,877	8	0
770 „	10 „ „	3	0	0	do	2,310	0	0
	Extra only over straight pipes for :—							
3,500 L.ft.	Hassall's double lined safety joint, (or equally good joint) in wet ground	0	1	0	L.ft.	218	12	0
600 No.	Bends	1	12	0	Each.	1,050	0	0
6,950 „	Oblique junctions, 6" × 4"	0	10	0	do	4,343	12	0
6,000 „	Stoppers	0	4	6	do	1,687	8	0
500 „	Traps for drop manholes	4	8	0	do	2,250	0	0
100 „	Modern traps for special cases, large houses, &c. ...	8	4	0	do	825	0	0
500 „	Oblique " drop " junctions, 6" × 6"	1	0	0	do	500	0	0
						1,50,137	8	0
	Sundries 5 % say ...					7,512	8	0
	Total carried to summary (page 155) ...					1,57,650	0	0

Pipe Sewers—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	9 inch Sewers.							
	9 inches internal diameter best English stoneware pipes laid complete, including excavation, pumping, timbering, laying, jointing and refilling :—							
370 L.ft.	3 feet deep to invert	1	7	0	L. ft.	531	14	0
4,230 „	4 „ „	1	8	0	do	6,345	0	0
3,260 „	5 „ „	1	9	0	do	5,093	12	0
3,870 „	6 „ „	2	6	0	do	9,191	4	0
4,140 „	7 „ „	2	10	0	do	10,867	8	0
5,060 „	8 „ „	2	14	0	do	14,547	8	0
6,560 „	9 „ „	3	2	0	do	20,500	0	0
2,930 „	10 „ „	3	7	0	do	10,071	14	0
1,650 „	11 „ „	4	3	0	do	6,909	6	0
1,050 „	12 „ „	4	9	0	do	4,790	10	0
600 „	13 „ „	5	0	0	do	3,000	0	0
1,020 „	14 „ „	5	8	0	do	5,610	0	0
520 „	15 „ „	6	2	0	do	3,185	0	0
	Extra only over straight pipes for :—							
20,110 L.ft.	Hassall's double-lined safety joint, (or equally good joint) in wet ground	0	2	0	L. ft.	2,513	12	0
1,132 No.	Oblique junctions	0	15	0	Each.	1,061	4	0
3,745 c.ft.	Concrete round pipes as ordered say 2,140 feet at $1\frac{3}{4}$ c. feet per foot run	50	0	0	100 c. ft.	1,872	8	0
50 No.	Taper pipes, 9 inch to 6 inch	3	12	0	Each.	187	8	0
						1,06,278	12	0
	Sundries, 5% say ...					5,311	4	0
	Total carried to summary (page 155) ...					1,11,590	0	0

Pipe Sewers—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	12 inch Sewers.							
	12 inches internal diameter best English stoneware pipes laid complete, including excavation, pumping, timbering, laying, jointing and refilling :—							
250 L.ft.	7 ft. deep to invert	3	5	0	L. ft.	828	2	0
290 „	8 „ „	3	9	0	do	1,083	2	0
110 „	9 „ „	3	13	0	do	419	6	0
210 „	10 „ „	4	4	0	do	892	8	0
370 „	11 „ „	5	0	0	do	1,850	0	0
3,890 „	12 „ „	5	5	0	do	20,665	10	0
970 „	13 „ „	5	13	0	do	5,638	2	0
1,770 „	14 „ „	6	4	0	do	11,062	8	0
1,090 „	15 „ „	7	0	0	do	7,630	0	0
390 „	16 „ „	7	12	0	do	3,022	8	0
	Extra only over Straight pipes for :—							
8,800 L.ft.	Hassall's double-lined safety joint (or equally good joint) in wet ground	0	3	0	do	1,650	0	0
488 No.	Oblique junctions	1	10	0	Each.	793	0	0
15,900 c.ft.	Concrete round pipes as may be ordered say 8480 L.ft. at $1\frac{7}{8}$ c.ft. per foot run	50	0	0	100 c.ft.	7,950	0	0
						63,434	14	0
						3,175	2	0
	Sundries 5 % say					66,610	0	0
	Total carried to summary (page 155) ...							

Pipe Sewers—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	15 inch Sewers.							
	15 inches internal diameter best English stoneware pipes laid complete, including excavation, laying, jointing and refilling :—							
350 L ft.	10 ft. deep to invert	5	9	0	L. ft.	1,946	14	0
760 „	11 „ „	6	7	0	do	4,892	8	0
490 „	12 „ „	6	12	0	do	3,307	8	0
640 „	13 „ „	7	6	0	do	4,720	0	0
530 „	14 „ „	7	13	0	do	4,140	10	0
1,300 „	15 „ „	8	7	0	do	10,968	12	0
700 „	16 „ „	9	4	0	do	6,475	0	0
	Extra only over straight pipes for :—							
4,770 L.ft.	Hassall's double-lined safety joint, (or equally good joint) in wet ground	0	4	0	do	1,192	8	0
264 No.	Oblique junctions	2	10	0	Each.	693	0	0
10,733 c.ft.	Concrete round pipes 4770 L.ft. at 2¼ c.ft. per foot. run	50	0	0	100 c.ft.	5,366	8	0
						43,703	4	0
	Sundries 5 % say ...					2,186	12	0
	Total carried to summary (page 155) ...					45,890	0	0

Pipe Sewers—(Contd.).

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	18 inch Sewers.							
	18 inches internal diameter best English stoneware pipes laid complete, including excavation, laying, jointing and refilling :—							
260 L.ft.	3 ft. deep to invert	4	3	0	L. ft.	1,088	12	0
80 „	4 „ „	4	4	0	do	340	0	0
250 „	6 „ „	5	7	0	do	1,359	6	0
200 „	7 „ „	5	10	0	do	1,125	0	0
150 „	9 „ „	6	4	0	do	937	8	0
200 „	11 „ „	7	13	0	do	1,562	8	0
160 „	14 „ „	9	10	0	do	1,540	0	0
660 „	16 „ „	11	9	0	do	7,631	4	0
430 „	17 „ „	12	12	0	do	5,482	8	0
	Extra only over straight pipes for :—							
1,600 L.ft.	Hassall's double-lined safety joint, (or equally good joint) in wet ground	0	6	0	do	600	0	0
82 No.	Oblique junctions	3	15	0	Each.	322	14	0
4,200 c.ft.	Concrete round pipes as ordered, say 1,600 L.ft. at $2\frac{5}{8}$ c.ft. per foot run	50	0	0	100 c.ft.	2,100	0	0
						24,089	12	0
	Sundries, 5 % say					1,200	4	0
	Total carried to summary (page 155) ...					25,290	0	0

24 inch Diameter Cast Iron Gravitation main from Pumping Station A to Pumping Station B.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Excavation including pumping, timbering, watching, lighting. Laying, and jointing, (including materials). Refilling and removing, surplus excavation for 24 inch Dia. C. I. pipes, 12 feet long, weighing about 24 cwt. each.							
140 L.ft.	3 feet deep	1	12	0	L.ft.	245	0	0
190 „	5 „	1	14	0	„	356	4	0
150 „	6 „	2	8	0	„	375	0	0
240 „	7 „	3	10	0	„	870	0	0
360 „	8 „	3	12	0	„	1,125	0	0
360 „	9 „	3	14	0	„	1,395	0	0
460 „	10 „	4	8	0	„	2,070	0	0
280 „	11 „	5	6	0	„	1,505	0	0
330 „	12 „	6	4	0	„	2,062	8	0
470 „	13 „	7	2	0	„	3,348	12	0
270 „	14 „	8	0	0	„	2,160	0	0
740 „	15 „	9	0	0	„	6,660	0	0
170 „	16 „	10	2	0	„	1,721	4	0
180 „	18 „	11	8	0	„	2,070	0	0
	Carried over ...					25,963	12	0

24 inch Diameter Cast Iron Gravitation main from Pumping Station A to Pumping Station B.—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Brought forward ...					25,963	12	0
4,280 L.ft.	Excavating, refilling, disjointing and taking up existing 24 inch pipes which are at present laid as a pumping main from Royapuram pumping station, cleaning pipes, coating with Siderosthen paint where necessary, and carting to trench side ...	2	0	0	L.ft.	8,560	0	0
4,280 „	Restoring road surface 7 feet wide	0	3	0	„	802	8	0
						35,326	4	0
	Sundries 5 % say ...					1,768	12	0
	Total carried to summary (page 155)...					37,095	0	0

34 inches Diameter Brick Gravitation Main from Pumping Station B to Chamber at head of 4′ 6″ sewer.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
33,660 c.ft.	Excavation, pumping, timbering, refilling, watering, ramming, lighting, watching, and removing surplus excavation	1	8	0	100 c.ft.	504	14	5
5,396 „	Concrete in special mortar	35	0	0	„	1,888	9	7
6,370 „	Brickwork, arched in special mortar	35	0	0	„	2,229	8	0
8,882 sq ft.	Plastering with cement, ½ inch thick	7	0	0	100 sq.ft.	621	11	10
12,804 „	Do do	5	0	0	„	640	3	2
700 L.ft.	Restoring road surface, 9 feet wide	0	4	0	L.ft.	175	0	0
						6,059	15	0
	Sundries 5 % say ...					300	1	0
	Total carried to summary (page 155) ...					6,360	0	0

Manholes.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Constructing a Circular Manhole, 3 ft. Deep to invert.							
135 c.ft.	Excavation, net outside pipe trench	1	0	0	100 c.ft.	1	5	7
37 „	Concrete in special mortar	35	0	0	100 „	12	15	2
26 „	Brickwork in special mortar	32	0	0	100 „	8	5	1
2 „	Well brick on edge	35	0	0	100 „	0	11	2
85 sq.ft.	Cement plastering, ½ inch thick	7	0	0	100 sq.ft.	5	15	2
2 No.	Foot irons	0	12	0	Each.	1	8	0
1 „	Manhole cover	20	0	0	„	20	0	0
	Total...					50	12	2
	Say Rs. 50...							
	Constructing a Circular Manhole, 8 ft. Deep to invert.							
404 c.ft.	Excavation, net outside pipe trench including timbering, pumping, &c.	6	0	0	100 c.ft.	24	3	10
49 „	Concrete in special mortar	35	0	0	100 „	17	2	5
83 „	Brickwork in special mortar	32	0	0	100 „	26	9	0
2 „	Well brick on edge	35	0	0	100 „	0	11	2
243 sq.ft.	Cement plastering, ½ inch thick	7	0	0	100 sq.ft.	17	0	2
6 No.	Foot irons	0	12	0	Each.	4	8	0
1 „	Manhole cover	20	0	0	„	20	0	0
	Total...					110	2	7
	Say Rs. 110...							
	Constructing a Circular Manhole 12 ft. Deep to invert.							
991 c.ft.	Excavation, net outside pipe trench, including timbering pumping, &c.	10	0	0	100 c.ft.	99	1	7
58 „	Concrete in Portland cement	55	0	0	100 „	31	14	5
126 „	Brickwork in special mortar	32	0	0	100 „	40	5	1
46 „	Do Portland cement mortar	50	0	0	100 „	23	0	0
2 „	Wall brick on edge	35	0	0	100 „	0	11	2
378 sq.ft.	Cement plastering, ½ inch thick	7	0	0	100 sq.ft.	26	7	4
9 No.	Foot irons	0	12	0	Each.	6	12	0
1 „	Manhole cover	20	0	0	„	20	0	0
	Total ..					248	3	7
	Say Rs. 250...							

Manholes—(Contd.)

Quantity.	Description of Works.	Rate.			Per	Amount.		
		Rs.	A.	P.		Rs.	A.	P.
	Constructing a Circular Manhole, 16 ft. Deep to invert.							
1,081 c.ft.	Excavation, net outside pipe trench, including timbering, pumping, &c.	18	0	0	100 c.ft.	194	9	3
72 „	Concrete in Portland cement	55	0	0	100 „	39	9	7
131 „	Brickwork in Portland cement mortar	50	0	0	100 „	65	8	0
116 „	Brickwork in special mortar	32	0	0	100 „	37	1	11
2 „	Well brick on edge	35	0	0	100 „	0	11	2
497 sq.ft.	Cement plastering, ½" thick	7	0	0	100 sq.ft.	34	12	8
13 No.	Foot irons	0	12	0	Each.	9	12	0
1 „	Manhole cover	20	0	0	„	20	0	0
	Total...					402	0	7
	Say Rs. 400...							
	Constructing a Circular Manhole, 20 ft. Deep to invert.							
1,070 c.ft.	Excavation, net outside pipe trench, including timbering, pumping, &c.	22	0	0	100 c.ft.	235	6	5
72 „	Concrete in Portland cement	55	0	0	100 „	39	9	7
203 „	Brickwork in Portland cement mortar	50	0	0	100 „	101	8	0
110 „	Do. in special mortar	32	0	0	100 „	35	3	2
2 „	Well brick on edge	35	0	0	100 „	0	11	2
655 sq.ft.	Cement plastering, ½" thick	7	0	0	100 sq.ft.	45	13	7
17 No.	Foot irons	0	12	0	Each.	12	12	0
1 „	Manhole cover	20	0	0	„	20	0	0
	Total...					490	15	11
	Say Rs. 490...							
	Constructing 6 inch P. Trap for Drop into Manhole.							
	Dry Ground.							
2 c ft.	Excavation extra only	6	0	0	100 c.ft.	0	1	11
2 „	Concrete in special mortar	35	0	0	„	0	11	2
	Total...					0	13	1
	Say Re. 1.							

Manholes—(Contd.)

Quantity.	Description of Works.	Rate.			Per	Amount.		
	Constructing 6 inch P. trap for drop into Manhole.	Rs.	A.	P.		Rs.	A.	P.
	Wet Ground.							
2 c. ft.	Excavation extra only	15	0	0	100 c.ft.	0	4	10
2 „	Concrete in Portland cement mortar	55	0	0	„	1	1	7
	Total...					1	6	5
	Say Re. 1-8-0 ...							
	Constructing 6 inch Branch for Drop in Manhole.							
	Dry Ground.							
1 c.ft.	Excavation extra only	6	0	0	100 c.ft.	0	1	0
3 „	Concrete in special mortar	35	0	0	„	1	0	10
	Total ...					1	1	10
	Say Re. 1-8-0 ...							
	Wet Ground.							
1 c.ft.	Excavation extra only	15	0	0	100 c.ft.	0	2	5
3 „	Concrete in Portland cement mortar	55	0	0	„	1	10	5
	Total ...					1	12	10
	Say Rs. 2-0-0 ...							
	Constructing Drop Shaft, cost per foot in Depth.							
	Dry Ground.							
1 c.ft.	Excavation extra only...	6	0	0	100 c.ft.	0	1	0
2 „	Concrete in special mortar	35	0	0	„	0	11	2
1 L.ft.	S. W. 6″ pipe	0	10	0	L.ft.	0	10	0
	Total ...					1	6	2
	Say Re. 1-8-0 ...							
	Wet Ground.							
1 c.ft.	Excavation extra only	15	0	0	100 c.ft.	0	2	5
2 „	Concrete in Portland cement	55	0	0	„	1	1	7
1 L.ft.	S. W. 6″ pipe	0	10	0	L.ft.	0	10	0
	Total ...					1	14	0
	Say Rs. 2-0-0 ...							

Manholes—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Constructing Chamber for Rider Sewers.							
1 c.ft.	Fine Portland cement concrete	35	0	0	100 c ft.	0	5	7
4·50 „	Granite stonework	3	0	0	C.ft.	13	8	0
8 sq. ft.	Cement plastering, ½ inch thick...	7	0	0	100 sq.ft.	0	9	0
1 No.	Iron handle	0	12	0	Each.	0	12	0
	Total ...					15	2	7
	Say Rs. 15 ...							
	Constructing Chamber for Gravitation Main on the Manhole.							
47 c.ft.	Excavation extra only...	6	0	0	100 c.ft.	2	13	1
26 „	Concrete in special mortar	35	0	0	„	9	1	7
27 „	Brickwork in special mortar	32	0	0	„	8	10	3
26 „	Archwork in special mortar	35	0	0	„	9	1	7
91 sq.ft.	Cement plastering, ½ inch thick	7	0	0	100 sq.ft.	6	5	11
	Total ...					36	0	5
	Say Rs. 36 ...							
	Constructing Extra Chamber at Junction of Rider Sewers and Street Sewers.							
20 c.ft.	Concrete in special mortar	35	0	0	100 c.ft.	7	0	0
34 „	Brickwork in special mortar	32	0	0	„	10	14	1
20 „	Archwork in special mortar	35	0	0	„	7	0	0
149 s.ft.	Cement plastering, ½ inch thick	7	0	0	100 sq.ft.	10	6	11
	Total ...					35	5	0
	Say Rs. 35 ...							

Manholes—(Contd.)

Number.	Description.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Summary of Cost as obtained from Estimates (pages 130 and 131.)							
89	3 feet deep to invert	50	0	0	Each.	4,450	0	0
67	4 „ do	63	0	0	„	4,221	0	0
80	5 „ do	70	0	0	„	5,600	0	0
63	6 „ do	83	0	0	„	5,229	0	0
52	7 „ do	90	0	0	„	4,680	0	0
53	8 „ do	110	0	0	„	5,830	0	0
34	9 „ do	138	0	0	„	4,692	0	0
24	10 „ do	175	0	0	„	4,200	0	0
21	11 „ do	210	0	0	„	4,410	0	0
26	12 „ do	250	0	0	„	6,500	0	0
13	13 „ do	290	0	0	„	3,770	0	0
22	14 „ do	325	0	0	„	7,150	0	0
22	15 „ do	360	0	0	„	7,920	0	0
10	16 „ do	400	0	0	„	4,000	0	0
4	17 „ do	432	0	0	„	1,728	0	0
1	19 „ do	498	0	0	„	498	0	0
	Extra only for "Drop" Connections in dry Ground (pages 131-2).							
40	1 foot deep	1	8	0	Each.	60	0	0
44	2 feet „	3	0	0	„	132	0	0
32	3 „	4	8	0	„	144	0	0
21	4 „	6	0	0	„	126	0	0
17	5 „	7	8	0	„	127	8	0
17	6 „	9	0	0	„	153	0	0
4	7 „	10	8	0	„	42	0	0
2	8 „	12	0	0	„	24	0	0
	Extra only for "Drop" Connections in wet Ground (pages 131-2).							
24	1 foot deep...	2	0	0	Each.	48	0	0
	Carried over...					75,734	8	0

Manholes—(Contd.)

Number.	Description.	Rate			Per	Amount.		
		Rs.	A.	P.		Rs.	A.	P.
	Brought forward ...					75,734	8	0
	Extra only for "Drop" Connections in wet Ground—(contd.)							
24	2 feet deep	4	0	0	Each.	96	0	0
6	3 „	6	0	0	„	36	0	0
13	4 „	8	0	0	„	104	0	0
7	5 „	10	0	0	„	70	0	0
72	Chambers for rider sewers (page 133)	15	0	0	„	1,080	0	0
12	Do gravitation main (page 133) ...	36	0	0	„	432	0	0
27	Do in-coming rider sewers (page 133) ...	35	0	0	„	945	0	0
114	6 inch P. trap in dry ground (page 131) ...	1	0	0	„	114	0	0
75	Do wet do (page 132)	1	8	0	„	112	8	0
164	Branch special in dry ground (page 132)... ...	1	8	0	„	246	0	0
8	Do. wet ground (page 132)... ...	2	0	0	„	16	0	0
						78,986	0	0
	Sundries, 5% say ...					4,014	0	0
	Total carried to summary (page 155) ...					83,000	0	0

Constructing Galvanized Iron Ventilating Shaft 25 feet high in average.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
64 c.ft.	Earthwork excavation and refilling and removing surplus excavation	0	8	0	100 c.ft.	0	5	1
17 „	Concrete in special mortar	35	0	0	„	5	15	2
265 lbs.	C. I. iron pipings and jointings	0	2	0	lb.	33	2	0
25 L.ft.	Ventilating galvanized shaft	1	8	0	L.ft.	37	8	0
1 No.	Cast iron ornamental corniceting	5	0	0	Each.	5	0	0
16 L.ft.	6″ stoneware pipes jointing, laying, earthwork complete	1	4	0	L.ft.	20	0	0
1 No.	6″ stoneware bend with plain stopper, etc., complete.	3	0	0	Each.	3	0	0
1 „	Lead joint with materials	2	0	0	„	2	0	0
	Total ...					106	14	3
	Sundries at 5 % say ...					5	1	9
						112	0	0
150 No.	Ventilating shaft as above	112	0	0	„	16,800	0	0
	Total carried to summary (page 155) ...					16,800	0	0

Timber left in Trenches.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
8,000 c.ft.	Mango planks	1	4	0	C.ft.	10,000	0	0
2,100 „	Teak struts	3	4	0	„	6,825	0	0
	Total carried to summary (page 155) ...					16,825	0	0

Constructing 450 Gallons Tank.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
395 c.ft.	Earthwork excavation, refilling, pumping, lighting, watching, profiling, timbering and removing surplus excavation	1	0	0	100 c.ft	3	15	2
76 „	Concrete in special mortar	35	0	0	100 „	26	9	7
113 „	Brickwork in special mortar	33	0	0	100 „	37	4	8
272 sq.ft.	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	21	12	2
11 „	Cuddapah slab, 3 inch thick	20	0	0	100 „	2	3	2
19 „	Wooden doors, with hinges, bolts, handle, &c., complete	1	4	0	sq ft.	23	12	0
1 No.	Silt-catcher with cover, &c., complete	4	0	0	Each.	4	0	0
1 „	C. I. special siphon with cap, &c., complete ...	70	0	0	„	70	0	0
1 „	Intercepting trap with stopper	6	0	0	„	6	0	0
2½ L.ft.	S. W. 4 inch pipe	0	6	0	L.ft.	0	15	0
	Total...					196	7	9
	Sundries, 5 %...					13	8	3
	Total...					210	0	0
25 No.	Flushing chamber	210	0	0	Each.	5,250	0	0
	Total carried to summary (page 155) ..					5,250	0	0

Constructing 900 Gallons Flushing Tanks.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
635 c.ft.	Earthwork excavation, refilling, pumping, lighting, watching, profiling, timbering and removing surplus excavation	1	0	0	100 c.ft.	6	5	7
122 „	Concrete in special mortar	35	0	0	100 „	42	11	2
182 „	Brickwork in special mortar	33	0	0	100 „	60	1	0
437 sq.ft.	Cement plastering, $\frac{5}{8}$ inch thick...	8	0	0	100 sq.ft.	34	15	4
18 „	Cuddapah slab, 3 inch thick	20	0	0	100 „	3	9	7
19 „	Wooden doors, with hinges, bolts, handle, &c., complete	1	4	0	Sq. ft.	23	12	0
1 No.	Silt-catcher with cover, &c., complete ...	4	0	0	Each.	4	0	0
1 „	C. I. special siphon with cap, &c., complete	113	0	0	„	113	0	0
1 „	Intercepting trap with stopper	12	0	0	„	12	0	0
2½ L.ft.	S. W. 4 inch pipe	0	6	0	L.ft.	0	15	0
	Total ...					301	5	8
	Sundries at 5 % say ...					13	10	4
	Total ...					315	0	0
2 No.	Flushing tank	315	0	0	Each.	630	0	0
	Total carried to summary (page 155) ...					630	0	0

Constructing 1,500 Gallons Flushing Tanks.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
1,222 c.ft.	Earthwork excavation, refilling, pumping, lighting, watching, profiling, timbering and removing surplus excavation	1	0	0	100 c.ft.	12	3	6
234 „	Concrete in special mortar	35	0	0	„	81	14	5
351 „	Brickwork in special mortar	33	0	0	„	115	13	3
841 sq.ft.	Plastering with cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	67	4	6
35 „	Cuddapah slab, 3 inch thick	20	0	0	„	7	0	0
19 „	Wooden doors, with hinges, bolts, handle, &c., complete	1	4	0	Sq.ft.	23	12	0
1 No.	Silt-catcher with cover, &c., complete	4	0	0	Each.	4	0	0
1 „	C. I. special siphon with cap., &c, complete ...	217	0	0	„	217	0	0
1 „	Intercepting trap with stopper	20	0	0	„	20	0	0
$2\frac{1}{2}$ L.ft.	S. W. 4 inch pipe	0	6	0	L ft.	0	15	0
						549	14	8
	Sundries 5 % ...					30	1	4
	Total ...					580	0	0
1 No.	Flushing tank	580	0	0	Each.	580	0	0
	Total carried to summary (page 155) ...					580	0	0

Restoring Road Surfaces on line of Sewers.

Quantity.	Description of Works.	Width of Restoration.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Sewers.								
1,01,500 L.ft.	6 inch	4 ft.	0	2	0	1 L.ft.	12,687	8	0
35,260 „	9 do.	5 „	0	2	6	„	5,509	6	0
9,340 „	12 do.	6 „	0	3	0	„	1,751	4	0
4,770 „	15 do.	6 „	0	3	0	„	894	6	0
2,390 „	18 do.	7 „	0	3	6	„	522	13	0
							21,365	5	0
	House Connections.								
60,000 L ft.	4 inch house connection 2 feet 6 inches ...		0	1	3	L.ft.	4,687	8	0
	Ventilating Shafts.								
2,400 L.ft.	6 inch shaft connection	2 ft. 6 in.	0	1	3	L.ft.	187	8	0
							26,240	5	0
	Sundries 5 % say ...						1,319	11	0
	Total carried to summary (page 155) ...						27,560	0	0

House Connections.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Cost of one connection.							
120 c.ft	Excavation for laying 20′ × 2′ × 4′	2	0	0	100 c.ft.	2	6	5
15 L.ft.	S. W. pipes 4″	0	5	0	L.ft.	4	11	0
1 No.	S. W. Siphon 4″	4	4	0	Each.	4	4	0
20 lbs.	Cement	2	0	0	100 lbs.	0	6	5
¼ prh.	Sand	0	1	5	prh.	0	0	4
2½ lbs.	Tarred yarn	0	2	0	lbs.	0	5	0
15 L.ft.	Labour for laying and carting pipes	0	3	6	L.ft	3	4	6
1 No.	C. I. Siphon cover	1	12	0	Each.	1	12	0
1 „	Silt-catcher bucket and cover	4	0	0	„	4	0	0
250 „	Brick	5	5	9	1,000	1	5	5
2½ prh.	Mortar	0	4	11	prh.	0	12	4
50 lbs.	Cement	2	0	0	100 lbs.	1	0	0
¼ prh.	Sand	0	1	5	prh.	0	0	4
1 No.	Iron strainer...	0	8	0	Each.	0	8	0
⅛ lb.	Bombay nails	0	1	6	lbs.	0	0	2
3 ft.	C. I. pipe 4″...	0	13	0	ft.	2	7	0
	Labour for constructing and carting the materials from Napier Park Stores to Tondiarpet ...					2	8	9
						29	11	8
	Sundries 5 % say ...					1	4	4
	Total ...					31	0	0
4,000 No.	House connections as above	31	0	0	each.	1,24,000	0	0
	Total carried to summary (page 155) ...					1,24,000	0	0

Emergency Overflows for Sewerage Area A.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
7,744 c.ft.	Earthwork excavation, refilling and removing surplus excavation	0	6	0	100 c.ft.	29	0	8
423 „	Brickwork in special mortar	33	0	0	„	139	9	5
249 „	Concrete in special mortar	35	0	0	„	87	2	5
97 „	Archwork in special mortar	35	0	0	„	33	15	2
832 sq.ft.	Plastering cement, $\frac{5}{8}$ inch thick...	8	0	0	100 sq.ft.	66	9	0
18 „	Teakwood flaps with necessary ironwork ...	1	0	0	S.ft.	18	0	0
232 L.ft.	12 inch stoneware pipes, supplying, laying and jointing, with earthwork	3	8	0	L.ft.	812	0	0
						1,186	4	8
	Sundries, 5 % say ...					58	11	4
	Total carried to summary (page 155) ...					1,245	0	0
	Emergency Overflows for Sewerage Area B.							
965 c.ft.	Earthwork excavation, refilling and removing surplus excavation	0	12	0	100 c.ft.	7	3	10
300 „	Brickwork in special mortar	33	0	0	„	99	0	0
89 „	Archwork in special mortar	35	0	0	„	31	2	5
26 „	Granite cover stones	2	8	0	C.ft.	65	0	0
24 „	Rough cut stonework as per drawing	2	12	0	„	66	0	8
3 No.	Manhole covers, cast iron	20	0	0	Each.	60	0	0
$2\frac{3}{4}$ „	Teakwood flaps with ironwork complete	15	0	0	„	41	4	0
447 sq.ft.	Plastering in cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	35	12	2
$2\frac{3}{4}$ No.	Cutting and making good to existing scoop drain ...	5	0	0	Each.	13	12	0
162 c.ft.	Concrete in special mortar	35	0	0	100 c.ft.	56	11	2
12 L.ft.	12 inch stoneware pipe sewer, supplying, laying, and jointing with earthwork complete	3	0	0	L.ft.	56	0	0
95 „	18 inch stoneware pipe sewer, supplying, laying and jointing complete including earthwork	4	4	0	„	403	12	0
						915	10	3
	Sundries, 5 % say ...					44	5	9
	Total carried to summary (page 155) ...					960	0	0

Emergency Overflow for Sewerage Area C.

Quantity.	Description of Work.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A	P.
15,668 c.ft.	Earthwork excavation, refilling and removing surplus excavation	0	8	0	100 c.ft.	78	5	5
205 „	Concrete in special mortar	35	0	0	„	71	12	0
2,921 „	Brickwork in special mortar	33	0	0	„	968	14	11
163 „	Archwork in special mortar	35	0	0	„	57	0	10
5,121 sqr.ft.	Plastering in cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	409	10	11
21 c.ft.	Granite stone set in cement	2	8	0	C.ft.	52	8	0
652 „	Pallavaram stone, 3 sides rough dressed	2	0	0	„	1,304	0	0
63 „	Random rubble pitching over 6" gravel packing ...	60	0	0	100 „	37	12	10
5 sq.ft.	Teakwood flap with double link hinges, etc., complete	1	4	0	sq.ft.	6	4	0
2,835 c.ft.	Removing and re-packing rough stone at sea defence.	3	0	0	100 c.ft.	85	0	10
84 „	Dismantling brickwork of old manhole	6	0	0	„	5	0	8
920 L.ft.	Soorki mortar jointing cover stones ...	3	0	0	100 L.ft.	27	9	7
2 No.	Manhole cast iron covers	20	0	0	Each	40	0	0
						3,139	0	0
	Sundries, 5 % say ...					161	0	0
	Total carried to summary (page 155) ...					3,300	0	0

Acquisition of Lands, Tondiarpet.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
10,000 sq.ft.	For Pumping Station A	300	0	0	1 grd. (2,400 sq. ft.)	1,250	0	0
30,800 „	For Pumping Station B	400	0	0	„(Say)	5,133	0	0
10,000 „	For Pumping Station C	200	0	0	„ „	833	0	0
2,736 „	From manhole C.P.13, to manhole C P.14 ...	450	0	0	„	513	0	0
345 L.ft.	Easement for sewer through cemetery, from manhole A.140, to manhole A.142.	65	0	0	100 L.ft.	224	0	0
						7,953	0	0
	Sundries at 5 % say ...					397	0	0
	Total carried to summary (page 156) ...					8,350	0	0

Type A. B. & C. Pumping Stations.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Engine House.							
11,277 c.ft.	Earthwork excavation, refilling, fencing, profiling, lighting, pumping, watching and removing surplus excavation	1	8	0	100 c.ft.	169	2	6
4,177 „	Concrete in special mortar	35	0	0	„	1,461	15	2
2,575 „	Brickwork in special mortar	33	0	0	„	849	12	0
76 „	Archwork in special mortar	35	0	0	„	26	9	7
7,728 sq ft.	Plastering cement, $\frac{5}{8}$"	8	0	0	100 sq.ft.	618	3	10
129 „	Teak doors, $\frac{1}{3}$ panelled and $\frac{2}{3}$ venetianed, frames, hinges, bolts, etc.	1	4	0	Sq. ft.	161	4	0
346 L.ft.	Concrete beams	1	0	0	1 L.ft	346	0	0
472 sq.ft.	Honeycomb work with pantiles cement mortar, whitewashing	7	8	0	100 sq.ft.	35	6	5
130 L.ft.	Teak hand railing	1	0	0	1 L.ft.	130	0	0
4,334 sq.ft.	Galvanized iron roofing with nuts, washers, bolts, etc., complete	37	0	0	100 sq.ft.	1,603	9	3
7,800 lbs.	Angle and tee iron purlins and rafters with bolts and nuts, washers complete	0	1	3	lb.	609	6	0
267 sq.ft.	Teak venetians fixed with frames	0	12	0	Sq.ft.	200	4	0
2 No.	Truss with W.I. shoes everything complete ...	80	0	0	No.	160	0	0
84 sq. ft.	Circular teak 2" plank flooring with joists ...	0	10	0	Sq.ft.	52	8	0
120 lbs.	W. I. portable ladder complete	0	1	3	lb.	9	6	0
3,166 c.ft.	Brickwork in special mortar	33	0	0	100 c.ft.	1,044	12	6
70 L.ft.	18" stoneware pipe 18' deep, supplying, laying and jointing, with materials and including earthwork	12	0	0	1 L.ft.	840	0	0
3 No.	Well-sinking, constructing with well bricks in cement mortar and chunam mortar, teakwood curb, plastering, $\frac{1}{8}$" cement, including all materials and labour	560	0	0	Each.	1,680	0	0
	Painting woodwork, etc.							
						9,998	3	3
	Sundries at 5 % say ...					501	12	9
	Total carried to summary (page 155) ...					10,500	0	0

Type A. B. & C. Pumping Stations—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A	P.
	Receiving and Screening Chamber.							
13,096 c.ft	Earthwork excavation, refilling pumping, profiling, lighting, watching and removing surplus excavation.	10	0	0	100 c.ft.	1,309	9	7
1,800 „	Concrete	55	0	0	„	990	0	0
2,000 „	Brickwork in cement, 2 to 1	60	0	0	„	1,200	0	0
2,720 „	Brickwork in special mortar	33	0	0	„	897	9	7
37 „	Arch brickwork in special mortar	35	0	0	„	12	15	2
500 „	Circular brickwork in cement mortar 2 to 1 with well bricks	65	0	0	„	325	0	0
588 „	Brickwork in special mortar circular work ...	35	0	0	„	205	12	10
4,839 sq.ft.	Plastering in cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	391	1	11
60 L.ft.	18″ dia. stoneware pipe laying, supplying, jointing with materials including earthwork 16′ deep complete.	11	8	0	L.ft.	690	0	0
1 No.	Conical manhole 6 feet diameter at bottom including materials and labour	400	0	0	Each.	400	0	0
						6,422	1	1
	Sundries at 5 % say ...					322	14	11
	Total carried to summary (page 155) ...					6,745	0	0
	Office, Store and Tools Room.							
1,778 c.ft.	Earthwork excavating, refilling, profiling, lighting, watching and removing surplus excavation ...	0	8	0	100 c.ft.	8	14	3
508 „	Concrete in special mortar	35	0	0	„	177	12	10
3,289 „	Brickwork in special mortar	33	0	0	„	1,085	5	11
42 „	Arch brickwork in special mortar	35	0	0	„	14	11	2
3,563 sq.ft.	Plastering chunam	2	8	0	100 sq.ft.	89	1	2
432 „	Flooring, 8″ × 8″ × 2″ square bricks pointed with cement over 6″ sand	8	8	0	„	36	11	6
84 „	Teakwood doors, panelled, with frames, hinges, bolts, etc., complete	1	0	0	Sq. ft.	84	0	0
45 „	Teak windows panelled, shutters, fittings $\frac{3}{4}$″ frames, bolts, hinges, etc.	1	4	0	„	56	4	0
12 c.ft.	Teakwood wrought and put up	3	12	0	C.ft.	45	0	0
	Carried over ...					1,597	12	10

Type A. B. and C. Pumping Stations.—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Office, Store and Tools Room—(Contd.)							
	Brought forward ...					1,597	12	10
990 sq.ft.	Roofing, Mangalore tiles teak rafters of 3" & 6" spaced 2 feet apart teak reepers, etc., complete... ..	32	0	0	100 sq.ft.	316	12	10
90 L.ft	Eaves board, teak 9" × ¾" ornamental with nailing ...	0	12	0	L. ft.	67	8	0
						1,982	1	8
	Painting ...				L. S.	45	0	0
	Total ...					2,027	1	8
	Sundries at 5 % say ...					102	14	4
	Total carried to summary (page 155) ..					2,130	1	0
	Constructing Latrine.							
481 c.ft.	Earthwork excavation, refilling and removing surplus excavation	1	0	0	100 c.ft.	4	12	11
330 „	Concrete in special mortar	35	0	0	„	115	8	0
640 „	Brickwork in special mortar	33	0	0	„	211	3	2
132 „	Archwork brick in special mortar	35	0	0	„	46	3	2
1,296 sq.ft.	Plastering cement, ⅝ inch thick	8	0	0	100 sq.ft.	103	10	11
16 „	Doors teak panelled with frames, hinges, bolts, etc., complete	1	0	0	Sq.ft.	16	0	0
42 „	Honeycomb work with pantiles in cement and white-washing	7	8	0	100 „	3	2	5
86 „	Cuddapah slabs, 2" in cement...	18	0	0	100 „	6	7	8
1 No.	Automatic tipping box for flushing latrine, supplying and fixing...	45	0	0	Each.	45	0	0
10 L.ft.	6" stoneware pipes, supplying, laying, jointing, with materials and including earthwork	1	4	0	L.ft.	12	8	0
338 sq.ft.	Roofing, Mangalore tiles, teak reepers, teak rafters, 2" × 5" centered 24" and nailing etc., complete ...	32	0	0	100 sq.ft.	108	2	7
3 c.ft.	Teakwood wrought and put up	3	12	0	c.ft.	11	4	0
26 L.ft.	Eaves board, teak, 9" × ¾"	0	12	0	L.ft.	19	8	0
						703	6	10
	Sundries at 5 % say ...					36	9	2
	Total carried to summary (page 156) ...					740	0	0

Type A. B. & C. Pumping Stations—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Constructing Compound Wall.							
2,625 c.ft.	Earthwork excavating, refilling, and removing surplus excavation	0	8	0	100 c.ft.	13	2	0
1,050 „	Concrete in special mortar	35	0	0	„	367	8	0
3,850 „	Brickwork in special mortar	33	0	0	„	1,270	8	0
350 L.ft.	Coping with chunam plaster	0	3	0	L.ft.	65	10	0
5,250 sq.ft.	Plastering chunam	2	8	0	100 sq. ft	131	4	0
2 No.	Gates, teakwood full battened, hinges, granite stones, guard stones, painting, fixing, etc., complete, 12 feet long by 4½ wide	80	0	0	Each.	160	0	0
						2,008	0	0
	Sundries at 5 % say...					102	0	0
	Total carried to summary (page 156) ...					2,110	0	0

Cost of Standard Silt Raising Apparatus at Stations A, B & C.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A	P.
	Silt-Raisers.							
63 ft.	8″ flanged C. I. pipes and fixing	6	0	0	Foot.	378	0	0
1 No.	8″ junction off pump main	30	0	0	Each.	30	0	0
1 „	8 × 8″ junction, fixed	32	0	0	„	32	0	0
4 „	Cast iron bends, fixed	23	0	0	„	92	0	0
12 ft.	Light screwed 5″ piping, fixed	4	0	0	Foot.	48	0	0
34 „	Do 2½″ do	2	0	0	„	68	0	0
2 No.	Screwed Junction boxes (1·6 cwts.) ...	30	0	0	Cwt.	48	0	0
2 „	Do do (·8 cwts.) ...	30	0	0	„	24	0	0
4 „	Do do (1·1 cwts.) ...	30	0	0	„	33	0	0
2 „	8″ Sluice valves and fixing	105	0	0	Each	210	0	0
2 „	Cast Iron Tee pipes	96	0	0	„	192	0	0
8 ft.	Light 8″ C. I. pipes fixed	6	0	0	Foot.	48	0	0
2 No.	I ight Disc valves on Tee Branches	25	0	0	Each.	50	0	0
2 „	Special light inner pipes 7″ diameter each about 23 ft. say 46 ft.	5	0	0	ft.	230	0	0
2 „	Special silt nozzles	40	0	0	Each.	80	0	0
2 „	Connecting piece for inner tubes	30	0	0	„	60	0	0
8 „	Short joists. (6·43 cwts.) ...	9	0	0	Cwt.	58	0	0
1 „	Floating arm and apparatus complete				L. S.	200	0	0
						1,881	0	0
	Screening Pits.							
1 ton	Angle-bar and fixing	8	0	0	Cwt.	160	0	0
6 No.	Screening cages complete (3 cwts. each) ...	20	0	0	„	360	0	0
2 „	Fixed screens above cages (2 cwts. each) ...	18	0	0	„	72	0	0
1 „	First class light derrick crane to lift one ton, with foundation, complete				L. S.	650	0	0
						1,242	0	0

Pumping Station A.

Quantity.	Description of Works.	Rate.			Per	Amount.		
		Rs.	A.	P.		Rs.	A.	P.
	Sill Raising Apparatus.							
	As per details on page 149					1,881	0	0
	Screening Apparatus.							
	As per details on page 149					1,242	0	0
	Valves, Penstocks and Pump Deliveries.							
4 No.	15″ sluice valves	240	0	0	Each.	960	0	0
5 „	15″ disc valves	80	0	0	„	400	0	0
11 ft.	8″ cast iron pipe (flanged) fixed	5	0	0	Foot.	55	0	0
6 „	12″ do.	7	0	0	„	42	0	0
40 „	15″ do.	8	0	0	„	320	0	0
4 No.	8″ bends, C. I.	15	0	0	Each.	60	0	0
2 „	Delivery junctions extra	25	0	0	„	50	0	0
3 „	8″ sluice valves	105	0	0	„	315	0	0
						5,325	0	0
	Contingencies, 5 % say ...					265	0	0
	Total carried to summary (page 156) ...					5,590	0	0

Pumping Station B.

Quantity.	Description of Works.	Rate. Rs	A.	P.	Per	Amount. Rs.	A.	P.
	Silt-Raising Apparatus.							
	As per details on page 149					1,881	0	0
	Screening Apparatus.							
	As per details on page 149					1,242	0	0
	Valves, Penstocks and Pump Deliveries.							
4 No.	18″ sluice valves and fixing	330	0	0	Each.	1,320	0	0
5 „	18″ disc valves and cover	150	0	0	„	750	0	0
11 ft.	12″ cast iron piping	7	0	0	Foot.	77	0	0
6 „	18″ do.	9	0	0	„	54	0	0
40 „	18″ do.	9	0	0	„	360	0	0
4 No.	12″ C. I. bend	20	0	0	Each.	80	0	0
2 „	Delivery junctions	30	0	0	„	60	0	0
3 „	12″ sluice valves	210	0	0	„	630	0	0
						6,454	0	0
	Sundries at 5 % say ...					326	0	0
	Total carried to summary (page 156) ...					6,780	0	0

Pumping Station C.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Silt-Raising Apparatus.							
	As per details on page 149					1,881	0	0
	Screening Apparatus.							
	As per details on page 149					1,242	0	0
	Valves, Penstocks and Pumps delivery							
4 No.	15″ sluice valves	240	0	0	Each.	960	0	0
5 „	15″ disc valves	80	0	0	„	400	0	0
11 ft.	8″ cast iron pipe (flanged)	5	0	0	Foot.	55	0	0
6 „	12″ do	7	0	0	„	42	0	0
40 „	15″ do	8	0	0	„	320	0	0
4 No.	8″ bends C. I.	15	0	0	Each.	60	0	0
2 „	Delivery junctions extra on delivery pipes... ...	25	0	0	„	50	0	0
3 „	8″ sluice valves	105	0	0	„	315	0	0
						5,325	0	0
	Sundries 5 % say ...					265	0	0
	Total carried to summary (page 156) ...					5,590	0	0

Pumping Plant for Station A.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	The pumping plant at station A is to consist of :— Centrifugal pumps driven by oil engines through helical gearing and to include all suction and delivery piping inside engine house, vacuum pumps for charging suction, oil engines for use with liquid fuel, with silencers, exhaust pipes and foundation bolts. Sets of cooling water tanks and connections. All fittings to make plant complete inside engine house							
3 No.	Sets of engines and pumps each capable of delivering 479 gallons per minute against a total head of 15 feet erected complete and run for one month ...					22,275	0	0
1 „	Venturi meter with recorder fixed complete ...					3,600	0	0
1 „	Pump pressure, and sewage level recorders ...					800	0	0
						26,675	0	0
	Add 5% say ...					1,325	0	0
	Total carried to summary (page 156) ...					28,000	0	0

Pumping Plant for Station B.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	The pumping plant at station B is to consist of :— Centrifugal pumps driven by oil engines through helical gearing and to include all suction and delivery piping inside engine house, vacuum pumps for charging suction, oil engines for use with liquid fuel, with silencers, exhaust pipes and foundation bolts. Sets of cooling water tanks and connections. All fittings to make plant complete inside engine house							
3 No.	Sets of engines and pumps, each capable of delivering 2,031 gallons per minute against a total head of 18 feet							
	Erected complete and run for one month ...					60,350	0	0
1 No.	Venturi meter with recorder fixed complete ...					4,200	0	0
1 „	Sewage level and pump pressure recorders ...					800	0	0
						65,350	0	0
	Sundries 5 % say ...					3,250	0	0
	Total carried to summary (page 156) ...					68,600	0	0

Pumping Plant for Station C.

Quantity.	Description of Works.	Rate.			Per	Amount.		
		Rs.	A.	P.		Rs.	A.	P.
	The pumping plant at station C is to consist of :— Centrifugal pumps driven by oil engines through helical gearing and to include all suction and delivery piping inside engine house, vacuum pumps for charging suction, oil engines for use with liquid fuel, with silencers, exhaust pipes and foundation bolts. Sets of cooling water tanks and connections. All fittings to make plant complete inside engine house							
3 No.	Sets of Engines and pumps, each capable of delivering 576 gallons per minute against a total head of 15 feet erected complete and run for one month ...					23,775	0	0
1 No.	Venturi meter with recorder fixed complete ...					3,600	0	0
1 „	Sewage level and pump pressure recorders ...					800	0	0
						28,175	0	0
	Sundries 5 % say ...					1,425	0	0
	Total carried to summary (page 156) ...					29,600	0	0

N

Summary of Estimates for Works required solely for the Drainage of Tondiarpet.

From Detailed Estimate Page.	Description of Works.	Amount.			Total.		
		Rs.	A.	P.	Rs.	A.	P.
	Sewers.						
123	6 inch pipe sewer (Stoneware)	1,57,650	0	0			
124	9 " "	1,11,590	0	0			
125	12 " "	66,610	0	0			
126	15 " "	45,890	0	0			
127	18 "	25,290	0	0			
128-9	24 " (Cast Iron)	37,095	0	0	4,07,030		
129	34 " (Brickwork)	6,360	0	0	1,50,485	0	0
134-5	Manholes	...	...	...	83,000	0	0
	General.						
136	Ventilating columns	16,800	0	0			
136	Timber left in trenches	16,825	0	0			
137-9	Flushing chambers	6,460	0	0			
140	Restoring road surfaces	27,560	0	0	67,645	0	0
141	House connection sewers	...	...	...	1,24,000	0	0
	Overflows.						
142	Area A	1,245	0	0			
142	" B	960	0	0			
143	" C	3,300	0	0	5,505	0	0
	Pumping Stations.						
	A						
145	Engine house	10,500	0	0			
146	Receiving chamber	6,745	0	0			
147	Office store and tools room	2,130	0	0			
	Carried over ...	19,375	0	0	7,30,635	0	0

Summary of Estimates for Works required solely for the Drainage of Tondiarpet—(Contd.)

From Detailed Estimate Page.	Description of Works.	Amount. Rs.	A.	P.	Total. Rs.	A.	P.
	Brought forward ...	19,375	0	0	7,30,635	0	0
	Pumping Stations—(Contd.)						
147	Latrine	740	0	0			
148	Compound wall	2,110	0	0			
149-150	Screens, silt raisers, cranes, penstocks, valves and pump deliveries	5,590	0	0			
153	Machinery	28,000	0	0	55,815	0	0
	B						
145-8	Engine house and offices as for station A	22,225	0	0			
151	Screens, silt-raisers, cranes, penstocks, valves and pump deliveries	6,780	0	0			
153	Machinery	68,600	0	0	97,605	0	0
	C						
145-8	Engine house and offices as for station A	22,225	0	0			
152	Screens, silt raisers, cranes, penstocks, valves and pump deliveries	5 590	0	0			
154	Machinery	29,600	0	0	57,415	0	0
144	Acquisition of land...	8,350	0	0	8,350	0	0
					9,49,820	0	0
	Contingencies and supervision 10 % say ...				95,180	0	0
	Total ..				10,45,000	0	0

APPENDIX.

Works not included in classes A and B.

	Pages.
ESTIMATES OF COST OF	
SHONE SYSTEM	158—162
FLUSHOUT LATRINE	163
NIGHTSOIL DEPOT	164
SEPTIC TANK	165
ACQUISITION OF LAND FOR NEW ROADS	166
ESTIMATE OF SAVING IN COST OF CONSERVANCY IN TONDIARPET THROUGH ADOPTING UNDERGROUND DRAINAGE COMBINED WITH FLUSHOUT LATRINES AND NIGHTSOIL DEPOTS ...	167

Shone System with G.O. Gradients involving 7 Ejector Stations.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Pipe Sewers.							
	6 Inch Sewers.							
	6 inches dia. best English stoneware pipes laid complete, including excavation, pumping, timbering, laying, jointing and refilling :—							
146,010 L.ft.	Average depth 8 ft. to invert	2	6	0	L.ft.	3,46,773	12	0
	Extra only over straight pipes for :—							
50,000 L.ft.	Hassall's double lined safety joint (or equally good joint) in wet ground...	0	1	0	L.ft.	3,125	0	0
600 No.	Bends	0	12	0	Each.	450	0	0
7,500 „	Oblique junctions, 6″×4″	0	10	0	„	4,687	8	0
7,000 „	Stoppers	0	4	6	„	1,968	12	0
500 „	Traps for drop manholes	4	8	0	„	2,250	0	0
500 „	Oblique " drop " junctions, 6″×6″	1	0	0	„	500	0	0
100 „	Modern traps for special cases	8	4	0	„	825	0	0
10,000 c.ft.	Concrete round pipes as required	50	0	0	100 c.ft.	5,000	0	0
						3,65,580	0	0
	Sundries 5% say ...					18,280	0	0
	Total carried to summary (page 162) ...					3,83,860	0	0
	9 Inch Sewers.							
	9 inches dia. best English stoneware pipes with Hassall's double lined safety joint, laid complete including excavation, pumping, timbering, laying, jointing and refilling : —							
5,780 L.ft.	Average depth 12 ft. to invert	4	9	0	L.ft.	26,371	4	0
	Extra only over straight pipes for :—							
500 No.	Oblique junctions	1	0	0	Each.	500	0	0
9,500 c.ft.	Concrete round pipes as may be ordered	50	0	0	100 c.ft.	4,750	0	0
59 No.	Taper pipes 9 inches to 6 inches	3	12	0	Each.	221	4	0
						31,842	8	0
	Sundries 5 % say ..					1,657	8	0
	Total carried to summary (page 162) ...					33,500	0	0

Shone System with G.O. Gradients involving 7 Ejector Stations—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	12 Inch Sewers.							
	12 inches dia. best English stoneware pipes with Hassall's double lined safety joint, laid complete including excavation, pumping, timbering, laying, jointing and refilling :—							
2,310 L.ft.	Average depth 14 ft. to invert	6	8	0	L.ft.	15,015	0	0
150 No.	Oblique junctions	1	10	0	Each.	243	12	0
4,500 c.ft.	Concrete round pipes as required	50	0	0	100 c.ft.	2,250	0	0
						17,508	12	0
	Sundries 5 °/₀ say ...					881	4	0
	Total carried to summary (page 162) ...					18,390	0	0
	Restoration of Road Surfaces.							
1,46,010 L.ft.	Trenches for 6 inches dia. pipes	0	2	0	L.ft.	18,251	4	0
5,780 „	Do do 9 do do	0	2	6	„	903	2	0
2,310 „	Do do 12 do do	0	3	0	„	433	2	0
						19,587	8	0
	Sundries 5 °/₀ say ...					982	8	0
	Total carried to summary (page 162) ...					20,570	0	0

Shone System with G.O. Gradients involving 7 Ejector Stations—(Contd.)

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Sewage Rising Mains.							
	Cast Iron pipes, laying and jointing including materials.							
4,010 L.ft.	9 inches diameter	3	0	0	L.ft.	12,030	0	0
1,920 „	12 do do	4	8	0	„	8,640	0	0
1,550 „	15 do do	6	8	0	„	10,075	0	0
6,280 „	18 do do	8	0	0	„	50,240	0	0
1,920 „	21 do do	10	0	0	„	19,200	0	0
4,70,400 c.ft.	Earthwork including excavation, timbering, pumping, refilling, lighting, fencing and removing surplus excavation	2	0	0	100 c.ft.	9,408	0	0
15,680 L.ft.	Road restoration	0	2	0	L.ft.	1,960	0	0
						1,11,553	0	0
	Sundries 5 % say...					5,577	0	0
	Total for sewage mains carried to summary (page 162)...					1,17,130	0	0
	Air Mains.							
	Cast Iron pipes laying and jointing.							
2,610 L.ft.	3 inches diameter	1	0	0	L.ft.	2,610	0	0
2,900 „	4 do do	1	4	0	„	3,625	0	0
1,550 „	6 do do	2	0	0	„	3,100	0	0
5,050 „	7 do do	2	8	0	„	12,625	0	0
1,420 „	8 do do	3	0	0	„	4,260	0	0
3,080 „	10 do do	3	8	0	„	10,780	0	0
2 49,150 c.ft.	Earthwork including excavation, timbering, pumping, refilling, lighting fencing and removing surplus excavation	2	0	0	100 c.ft.	4,983	0	0
16,610 L.ft.	Road restoration	0	2	0	L.ft.	2,076	4	0
						44,059	4	0
	Sundries 5 % say...					2,210	12	0
	Total for air mains carried to summary (page 162)...					46,270	0	0

Shone System with G.O. Gradients involving 7 Ejector Stations—(Contd.)

Quantity.	Description of Works.	Rate.			Per	Amount.		
		Rs.	A.	P.		Rs.	A.	P.
	Estimate for one Ejector Station.							
	Cast iron tubbing	included in machinery.						
5,350 c.ft.	Earthwork including excavation, timbering, pumping, refilling, fencing, lighting, restoring road surface and carting away surplus excavation ...	10	0	0	100 c.ft.	535	0	0
450 „	Concrete 4 to 1 in cement mortar	70	0	0	„	315	0	0
1 No.	Manhole	110	0	0	Each.	110	0	0
1 No.	Filtering and silencing chamber...	150	0	0	„	150	0	0
						1,110	0	0
	Add sundries 5 % say...					60	0	0
	Total for one station...					1,170	0	0
7 No.	Cost of 7 stations	1,170	0	0	Each.	8,190	0	0
	Total for 7 Ejector Stations carried to summary (page 162).							

Shone System with G. O. Gradients involving 7 Ejector Stations.

Summary of Estimates.

From page.	Description of Works.	Amount. Rs.	A.	P.	Total. Rs.	A.	P.
	Laying Pipe Sewers.						
158	6 inch sewers	3,83,860	0	0			
158	9 do do	33,500	0	0			
159	12 do do	18,390	0	0	4,35,750	0	0
136	Timber left in				16,825	0	0
141	House connection sewers				1,24,000	0	0
159	Restoration of road surfaces				20,570	0	0
135	Manholes				83,000	0	0
136	Ventilating shafts				16,800	0	0
137	Flushing chambers				5,000	0	0
160	Cast iron sewage raising mains				1,17,130	0	0
160	Do do air mains				46,270	0	0
144	Easements				224	0	0
144	Acquisition of land				513	0	0
	Buildings, etc.						
161	Ejector stations	8 190	0	0			
	Air compressor station	16,500	0	0			
147	Office and tool house	2,130	0	0			
147	Latrine	740	0	0			
	Acquisition of land...	6,000	0	0			
148	Compound wall	2,110	0	0	35,670	0	0
	Machinery, etc.						
	Ejectors, tubbing and accessories	1,81,650	0	0			
	Chimney	3,000	0	0			
	Air compressors	1,08,640	0	0	2,93,290	0	0
					11,95,042	0	0
	Establishment 15 % say...				1,78,958	0	0
	Total .				13,74,000	0	0

Typical Latrine.

[Eight Compartments.]

Quantity.	Description of Works	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Drawing No. 47.							
1,147 c.ft.	Earthwork excavation, refilling and removing surplus excavation	0	8	0	100 c.ft.	5	11	9
230 „	Hard laterite	20	0	0	„	46	0	0
130 „	Concrete in cement	45	0	0	„	58	8	0
120 „	Concrete in special mortar	35	0	0	„	42	0	0
850 „	Brickwork in special mortar	33	0	0	„	280	8	0
20 sq.ft.	Granite stone	2	8	0	Sq.ft.	50	0	0
1,600 „	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	128	0	0
340 „	Roofing with Mangalore tiles, teakwood reepers and rafters (2 ins. ×4 ins.) 18 ins. apart—supplying and fixing with nails, &c., complete	34	0	0	„	115	9	7
88 L.ft.	Eaves board (teakwood) 9 ins. × $\frac{3}{4}$ in.	0	12	0	L.ft.	66	0	0
9 No.	Water-pipe $1\frac{1}{2}$ ins. connection from water main with self-closing ablution taps and necessary piping, &c. complete	12	0	0	Each.	108	0	0
1 „	Silt-catcher supplying and fixing, &c., complete ...	4	8	0	„	4	8	0
4 L.ft.	Stoneware 6 inches pipe, supplying, laying and jointing, &c., complete	1	4	0	4 L.ft.	5	0	0
8 No.	Stoneware 6 inches Tee junction pipes, supplying, laying and fixing, &c., complete	4	8	0	Each	36	0	0
1 „	Stoneware 6 inches cascade siphon supplying and fixing, &c., complete...	8	0	0	„	8	0	0
60 sq.ft.	Light teak flap-doors with nailings, &c., complete.	1	4	0	Sq.ft.	75	0	0
425 lbs.	Ironwork for upright small Tee angles, holes drilled, with bolts, washers and nuts, supplying and fixing &c., complete	0	1	6	lbs.	39	13	6
32 No.	Hinges in pairs with bolts washers, nails, &c., complete	2	0	0	Each.	64	0	0
1 „	Sheet iron tipping box for waste-water, with axles and bearings fitted in, supplying and fixing, &c., complete	45	0	0	„	45	0	0
600 sq.ft.	Painting two coats of colour	2	4	0	100 sq ft.	13	8	0
						1,191	2	10
	Sundries 5% say ...					58	13	2
						1,250	0	0
	Establishment and supervision 10% say ...					120	0	0
	Total ..					1,370	0	0

Note.—The above latrine is for use in good districts A cheaper form would be used in paracherries ; the saving in cost would be effected by adopting cheaper roofing and masonry.

Large Nightsoil Depot.

Quantity.	Description of Works.	Rate. Rs.	A.	P.	Per	Amount. Rs.	A.	P.
	Drawing No 62.							
3,240 c.ft.	Earthwork excavation, refilling and removing surplus excavation	0	8	0	100 c.ft.	16	3	2
875 „	Concrete in special mortar	35	0	0	„	306	4	0
1,038 „	Brickwork in special mortar	33	0	0	„	342	8	8
35 „	Archwork in special mortar	35	0	0	„	12	4	0
2,040 sq.ft.	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	163	3	2
5 c.ft.	Granite foot stone in cement	2	8	0	C.ft.	12	8	0
144 L.ft.	Pallavaram stone curb, 9 inches deep and fixing on edge	0	9	0	L.ft.	81	0	0
504 sq.ft.	Pallavaram stone 6 in. setts, bedded in sand and grouted with special cement mortar	54	0	0	100 sq.ft.	272	2	7
1,440 „	Light galvanized iron roofing 18 B. W. G. with trusses washers and nuts complete	28	0	0	„	403	3	2
1 No.	Cast iron 12 inches bend with valve lever and accessories complete	35	0	0	Each.	35	0	0
1 „	$1\frac{1}{2}$ inches connection for flushing tank including tap and piping	70	0	0	„	70	0	0
2 „	Large sluicing jet, with valve, flexible hose, nozzle, 3 in. piping and with 4 in. main, &c., supplying and fixing complete	140	0	0	„	280	0	0
1 „	Disc-valve for outlet into sewer, with handle complete	20	0	0	„	20	0	0
720 lbs.	Angle iron for purlins, including fish plates, bolts and nuts, &c.	0	1	3	lbs.	56	4	0
330 „	Tee iron for uprights, &c.	0	1	6	„	30	15	0
800 „	Cast iron loose gratings as per drawings ...	0	1	0	„	50	0	0
45 L.ft.	Stoneware 12 inches pipe supplying, laying and jointing including earthwork	4	0	0	L.ft.	180	0	0
300 sq.ft.	Painting 2 coats colours	2	4	0	100 sq.ft.	6	12	0
						2,338	3	9
	Sundries 5 % say ...					117	12	3
						2,456	0	0
	Establishment and supervision 10 % say ..					244	0	0
	Total ...					2,700	0	0
	N. B.—This estimate is for a depot where two carts can discharge simultaneously. The cost of a smaller type where only one cart would discharge at a time—would be about Rs. 1,500							

Typical Septic Tank for Drainage of Isolated places--capacity 4,500 gallons.

Quantity.	Description of Works.	Rate.			Per	Amount.		
	Drawing No. 49.	Rs.	A.	P		Rs.	A.	P.
2,835 c.ft.	Earthwork excavation, refilling and removing surplus excavation	0	8	0	100 c.ft.	14	2	10
350 „	Concrete in special mortar	35	0	0	100 „	122	8	0
1,110 „	Brickwork in special mortar	33	0	0	100 „	366	4	10
1,112 sq.ft	Plastering cement, $\frac{5}{8}$ inch thick	8	0	0	100 sq.ft.	88	15	4
642 „	Plastering chunam	2	8	0	100 „	16	0	10
181 „	3 ins. Cuddapah slabs in cement	26	0	0	100 „	47	1	0
66 „	2 ins. do do	18	0	0	100 „	11	14	1
2 c.ft.	Teakwood covers for silt pit, etc., wrought and put up.	3	12	0	C.ft.	7	8	0
50 lbs.	W. I. hinges, rings, etc., complete	0	2	0	lbs.	6	4	0
3 No.	C. I. Manhole covers, supplying and fixing complete..	20	0	0	Each.	60	0	0
1 „	6" stoneware gas intercepting siphon, supplying and fixing	8	0	0	Each.	8	0	0
7 L.ft.	6 inch stoneware pipe, supplying and laying complete	1	4	0	L.ft.	8	12	0
4 No.	6 inch stoneware special bends, supplying and fixing complete	3	8	0	Each.	14	0	0
						771	6	11
	Sundries 5 % say ..					38	9	1
						810	0	0
	Establishment and supervision 10 % say...					80	0	0
	Total...					890	0	0

Estimate of cost of land required for new Streets (not included in cost of Tondiarpet Scheme.)

Quantity.	Description of Works.	Rate.			Per	Amount.		
		Rs	A.	P.		Rs.	A.	P.
	"Sewerage Area B."							
5,520 sq.ft.	From manhole B. 99 to manhole B. 189 ..	250	0	0	Grd.	575	0	0
5,088 „	„ B. 98 „ B. 188 ...	250	0	0	„	530	0	0
4,800 „	„ B. 77 „ B. 141 ...	250	0	0	„	500	0	0
4,080 „	„ B. 96 „ B. 140 ...	250	0	0	„	425	0	0
17,220 „	„ A. P. 26 „ B. 139 ...	250	0	0	„	1,794	0	0
4,800 „	„ A. P. 27 „ B. Pumping Station...	250	0	0	„	500	0	0
						4,324	0	0
	Sundries 5 % say ..					216	0	0
	Total ..					4,540	0	0

Q

Estimate of saving in cost of conservancy in Tondiarpet through adopting underground drainage combined with Flushout Latrines, and Nightsoil Depots.

Description.	As now required.				As required after introduction of underground drainage combined with nightsoil depots and flushout latrines.			
	No.	Rate.		Amount.	No.	Rate.		Amount.
		Rs.	A. P.	Rs. A. P.		Rs.	A. P.	Rs. A. P.
Side drain maistries	3	7	8 0	22 8 0	...	...	... ...	... .
Side drain coolies	48	6	0 0	288 0 0	6	6	0 0	36 0 0
Cartmen	15	6	0 0	90 0 0	8	6	0 0	48 0 0
Barrel cartmen	21	6	8 0	136 8 0	...	...	... ...	... .
Cesspool boys	3	3	0 0	9 0 0	..	...	... ...	... .
Hand cartmen	7	6	0 0	42 0 0	...	...	... ...	... ...
Latrine men (double)	19	6	8 0	123 8 0	11	6	8 0	71 8 0
Do (single)	3	6	0 0	18 0 0	2	6	0 0	12 0 0
Latrine women (double)	16	4	8 0	72 0 0	8	4	8 0	36 0 0
Do (single)	5	3	8 0	17 8 0	3	3	8 0	10 8 0
Lorries	3	28	0 0	84 0 0	...	...	... ...	... .
Nightsoil carts	41	25	0 0	1,025 0 0	25	25	0 0	625 0 0
Box-carts	14	25	0 0	350 0 0	8	25	0 0	200 0 0
Nightsoil cart-drivers	41	5	0 0	205 0 0	25	5	0 0	125 0 0
Box-cart drivers	14	7	0 0	98 0 0	8	7	0 0	56 0 0
Lorry-drivers	3	7	0 0	21 0 0	...	...	... ...	... ...
Total...				2,602 0 0				1,220 0 0

Saving = Rs. 2,602—Rs. 1,220

= Rs. 1,382 per month

= Rs. 16,584—per annum...

Thompson & Co., Printers, Madras.

PHYSIOGRAPHICAL MAP OF TONDIARPET

SCALE 8·8 INCHES = 1 MILE

FIG NO 1

PLATE No. 1.

SPECIAL ENGI
CORPORATION OF
MARCH 190

DRAINAGE OF SOUTH TONDIARPET

PUMPING STATIONS REQUIRED IF GRADIENTS RECOMMENDED TO IN G. O. 1671 M ARE US

SCALE 3·3 INCHES = 1 MILE

NOTE:- THE PUMPING STATIONS ARE SHEWN BY RED CIRCLES.
THE BOUNDARIES OF AREAS DRAINING TO PUMPING STATIONS ARE SHEWN BY RED LINES.

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MARCH 1909.

~~FIG NO. 1.~~

PLATE No. 2.

DIAGRAM SHEWING RATE OF FLOW OF SEWAGE

AT

LANG'S GARDEN PUMPING STATION.

EXPLANATION.

FULL BLACK LINE.– *Shews rate of flow as measured every half hour by counting Pump Strokes.*

DOTTED FINE LINE.– *Shews rate of flow, when pumps were stopped, as estimated by rise of sewage in Receiving Well and in Pump Well.*

RED LINE.– *Shews probable approximate actual rate of flow.*

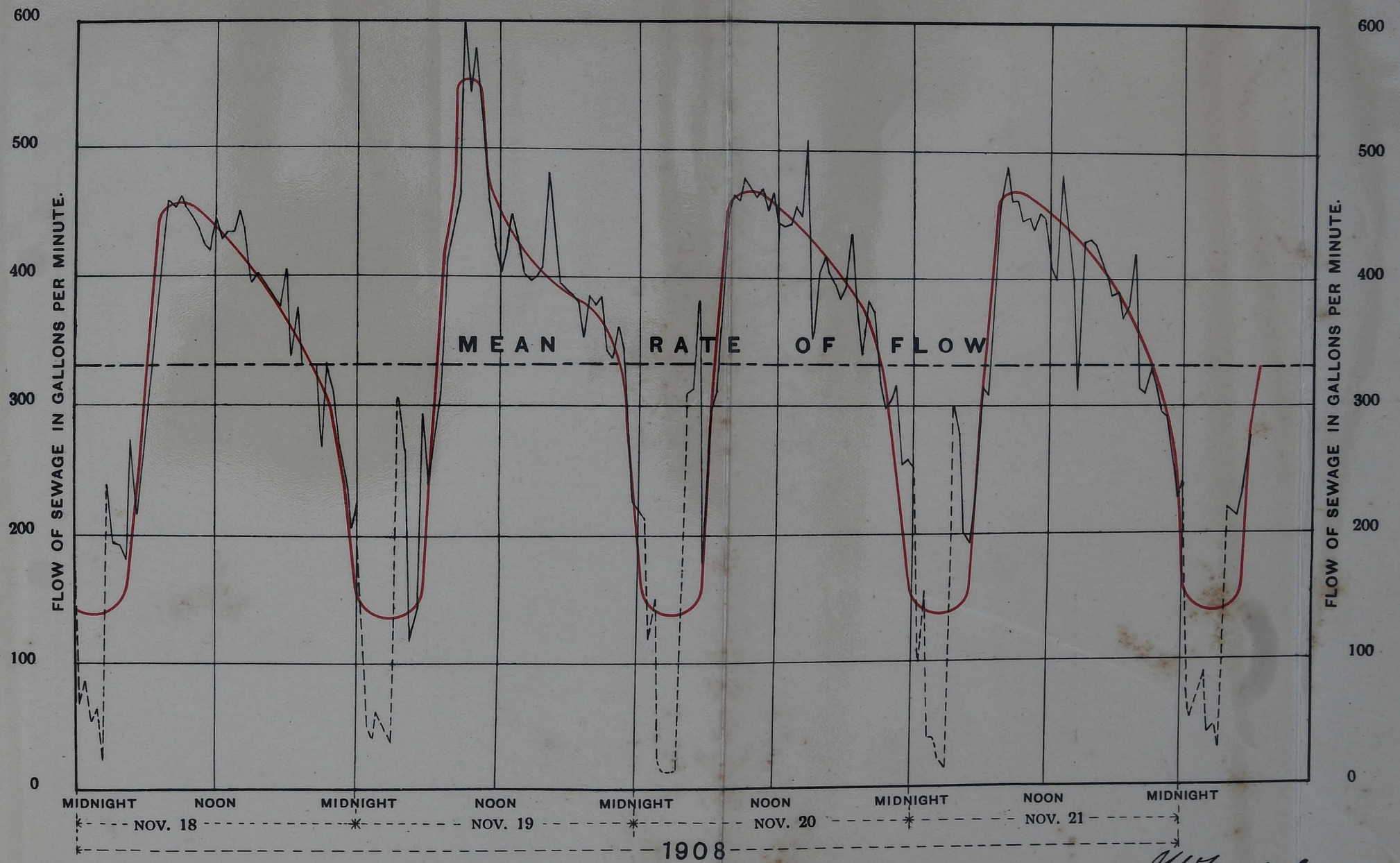

PLATE No. 3.

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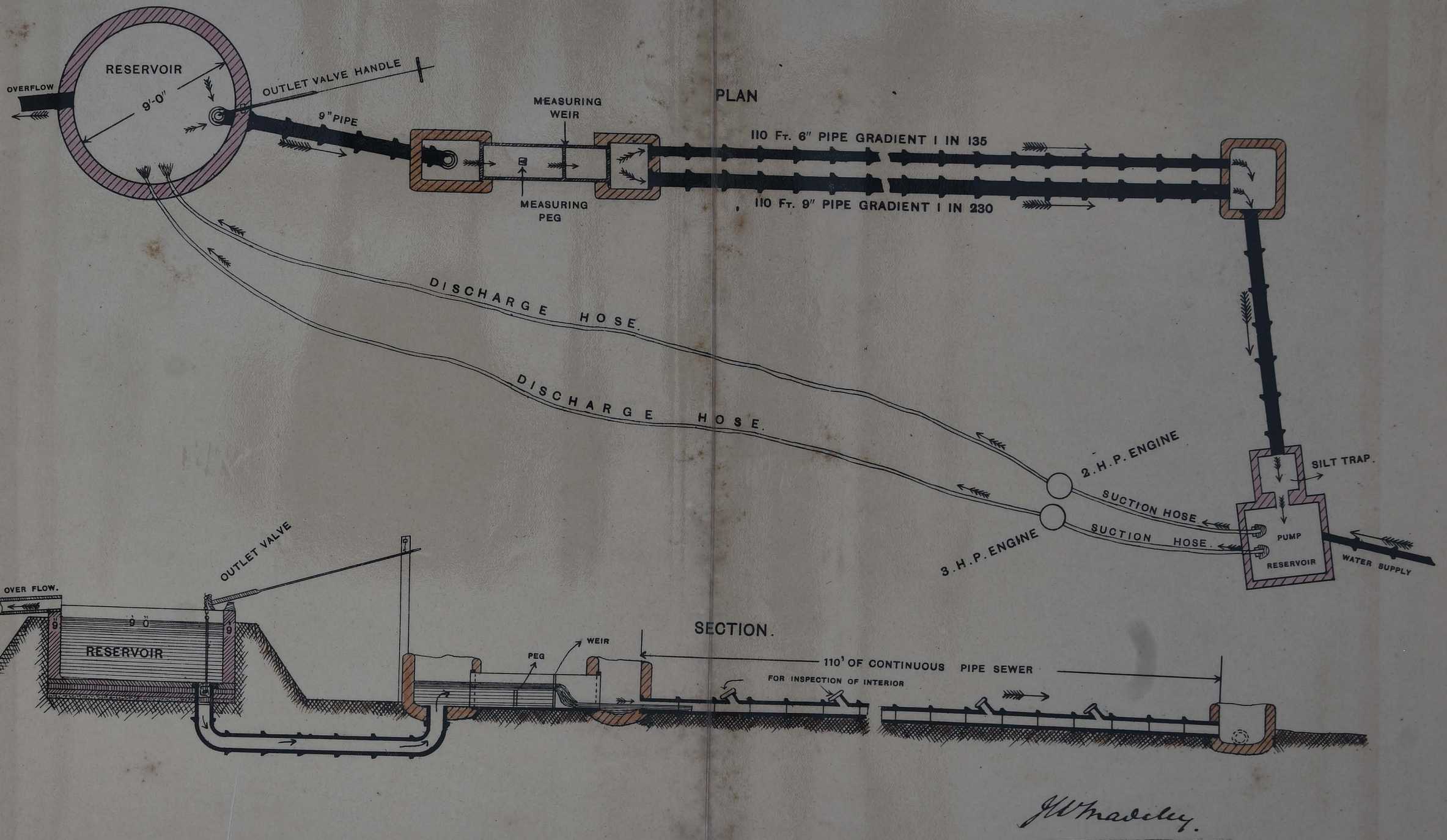
MARCH 1909.

EXPERIMENTS AT NAPIER PARK.

TO DETERMINE THE VELOCITY AND SILT CARRYING POWER OF
SEWAGE IN 6″ AND 9″ PIPE SEWERS LAID AT THE FLATTEST PROPOSED GRADIENTS.

SCALE 1 Inch = 5 Feet



J.W. Madeley.

SPECIAL ENGINEER
CORPORATION OF MADRAS
MARCH 1909.

FIG No. 4

PLATE No. 4.

DIAGRAM SHOWING VELOCITY OF FLOW AND DISCHARGING CAPACITY OF 6 INCH AND 9 INCH STONEWARE PIPES LAID AT THE FLATTEST GRADIENT PROPOSED FOR TONDIARPET

PLATE No 5

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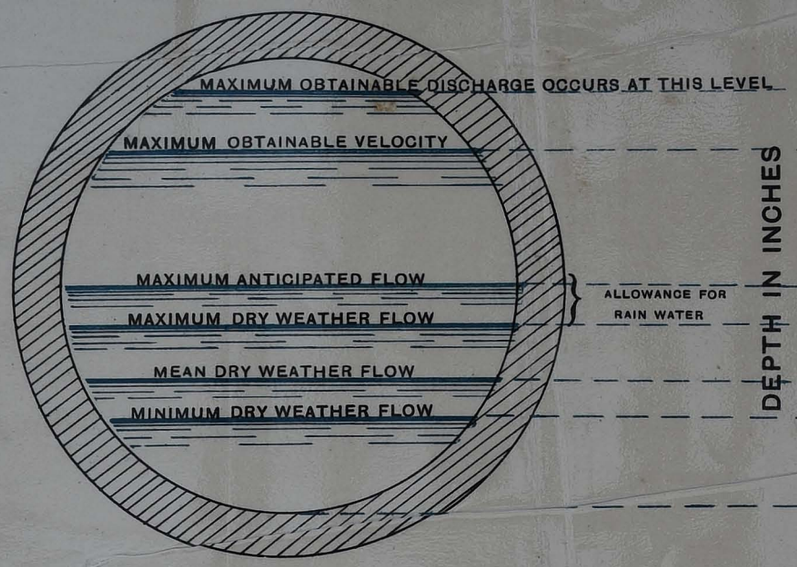
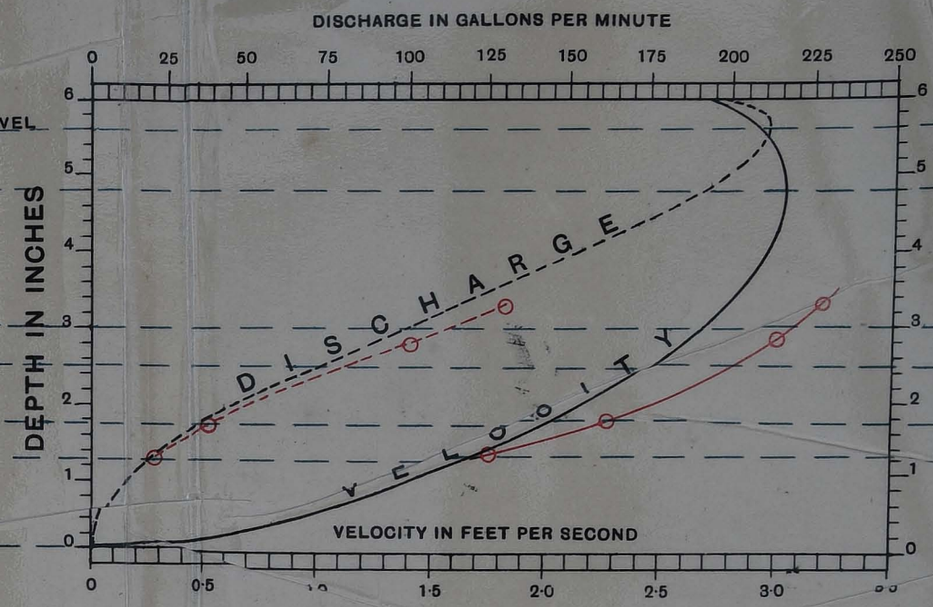
EXPLANATION:—

The Black Lines show the Velocities and Discharges as calculated from Santo Crimp's Tables.

The Red Lines show the same Quantities as determined by Experiment at Napier Park.

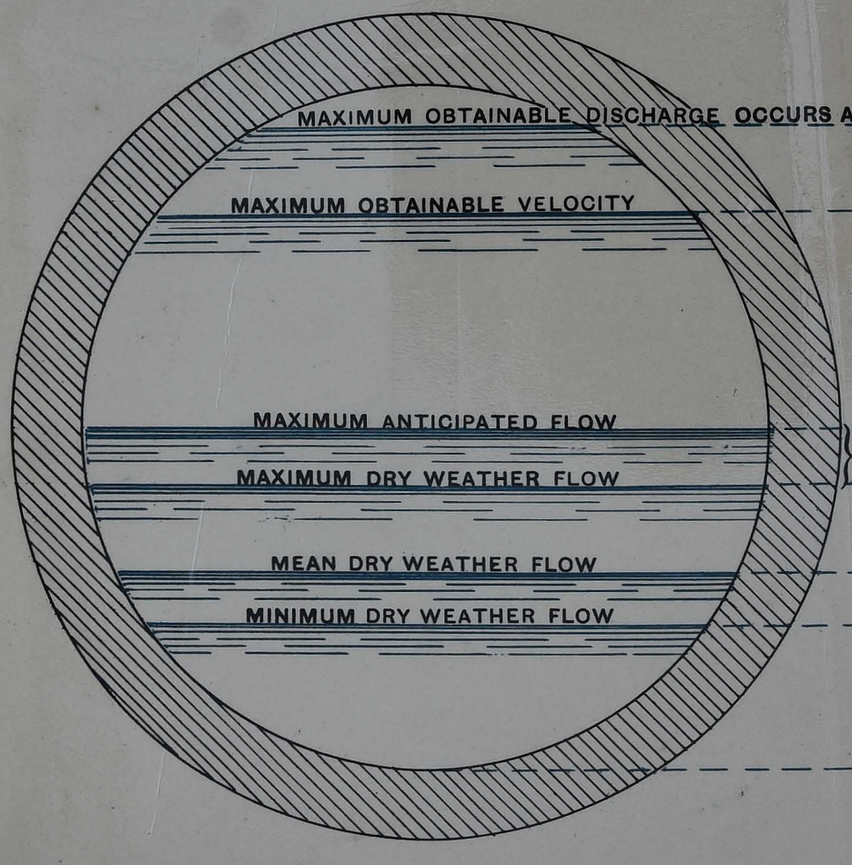
6 INCH PIPE— GRADIENT 1 IN 135

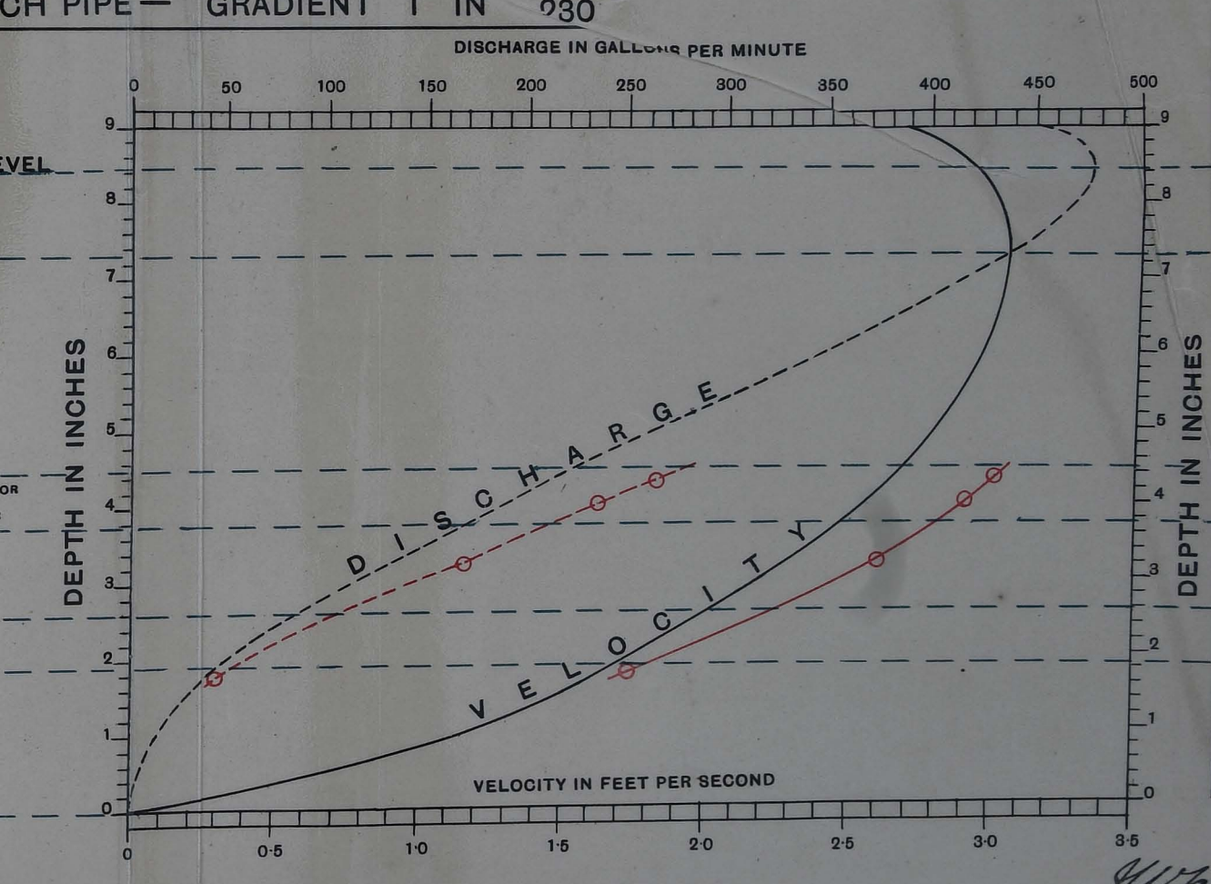

MAXIMUM OBTAINABLE DISCHARGE OCCURS AT THIS LEVEL
MAXIMUM OBTAINABLE VELOCITY
MAXIMUM ANTICIPATED FLOW
MAXIMUM DRY WEATHER FLOW
MEAN DRY WEATHER FLOW
MINIMUM DRY WEATHER FLOW
ALLOWANCE FOR RAIN WATER


DISCHARGE IN GALLONS PER MINUTE
0 25 50 75 100 125 150 175 200 225 250
DEPTH IN INCHES
0 1 2 3 4 5 6
DISCHARGE
VELOCITY
VELOCITY IN FEET PER SECOND
0 0·5 1·0 1·5 2·0 2·5 3·0

VELOCITY IN FEET PER SECOND.	DISCHARGE IN GALS. PER MINUTE.
2·66	196·0
2·93	210·8
3·02	197·4
3·03	193·9
2·94	153·3
2·66	98·0
2·46	73·5
2·18	47·6
2·03	36·80
1·68	18·40
1·45	12·80

9 INCH PIPE— GRADIENT 1 IN 230


MAXIMUM OBTAINABLE DISCHARGE OCCURS AT THIS LEVEL
MAXIMUM OBTAINABLE VELOCITY
MAXIMUM ANTICIPATED FLOW
MAXIMUM DRY WEATHER FLOW
MEAN DRY WEATHER FLOW
MINIMUM DRY WEATHER FLOW
ALLOWANCE FOR RAIN WATER


DISCHARGE IN GALLONS PER MINUTE
0 50 100 150 200 250 300 350 400 450 500
DEPTH IN INCHES
0 1 2 3 4 5 6 7 8 9
DISCHARGE
VELOCITY
VELOCITY IN FEET PER SECOND
0 0·5 1·0 1·5 2·0 2·5 3·0 3·5

VELOCITY IN FEET PER SECOND.	DISCHARGE IN GALS. PER MINUTE.
2·68	444·0
2·95	477·6
3·02	468·90
3·06	439·20
3·05	420·20
2·96	347·20
2·79	264·40
2·68	222·00
2·54	181·80
2·48	166·50
2·20	107·80
2·04	83·25
1·75	49·60
1·70	41·63
1·14	12·60

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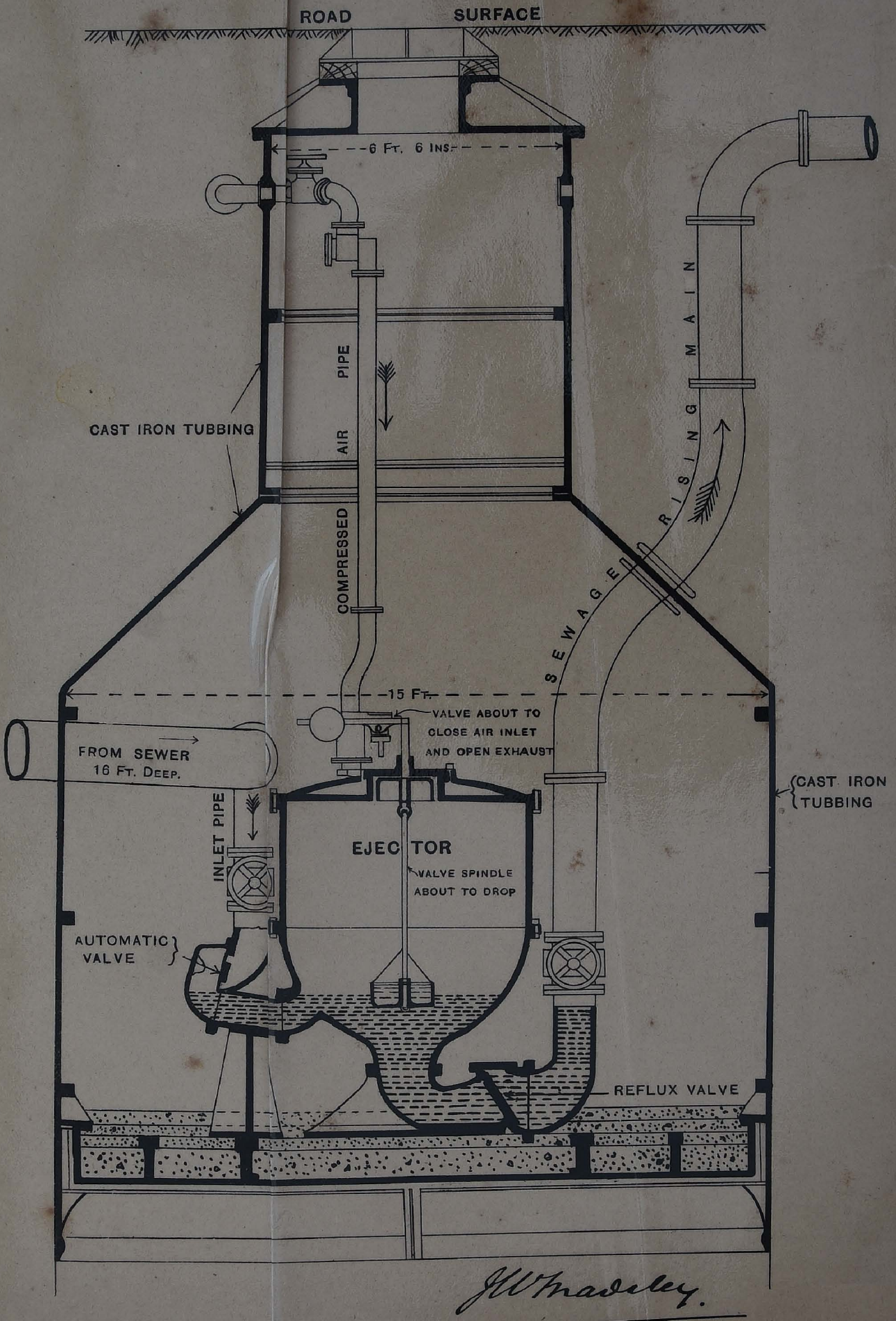
MARCH 1909.

EJECTOR IN CAST IRON TUBBING

PLATE No. 6.



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MARCH 1909

TYPICAL FIRST CLASS HOUSE DRAINAGE (FOR FULL DETAILS SEE DRAWING No 43)

PLATE No 7

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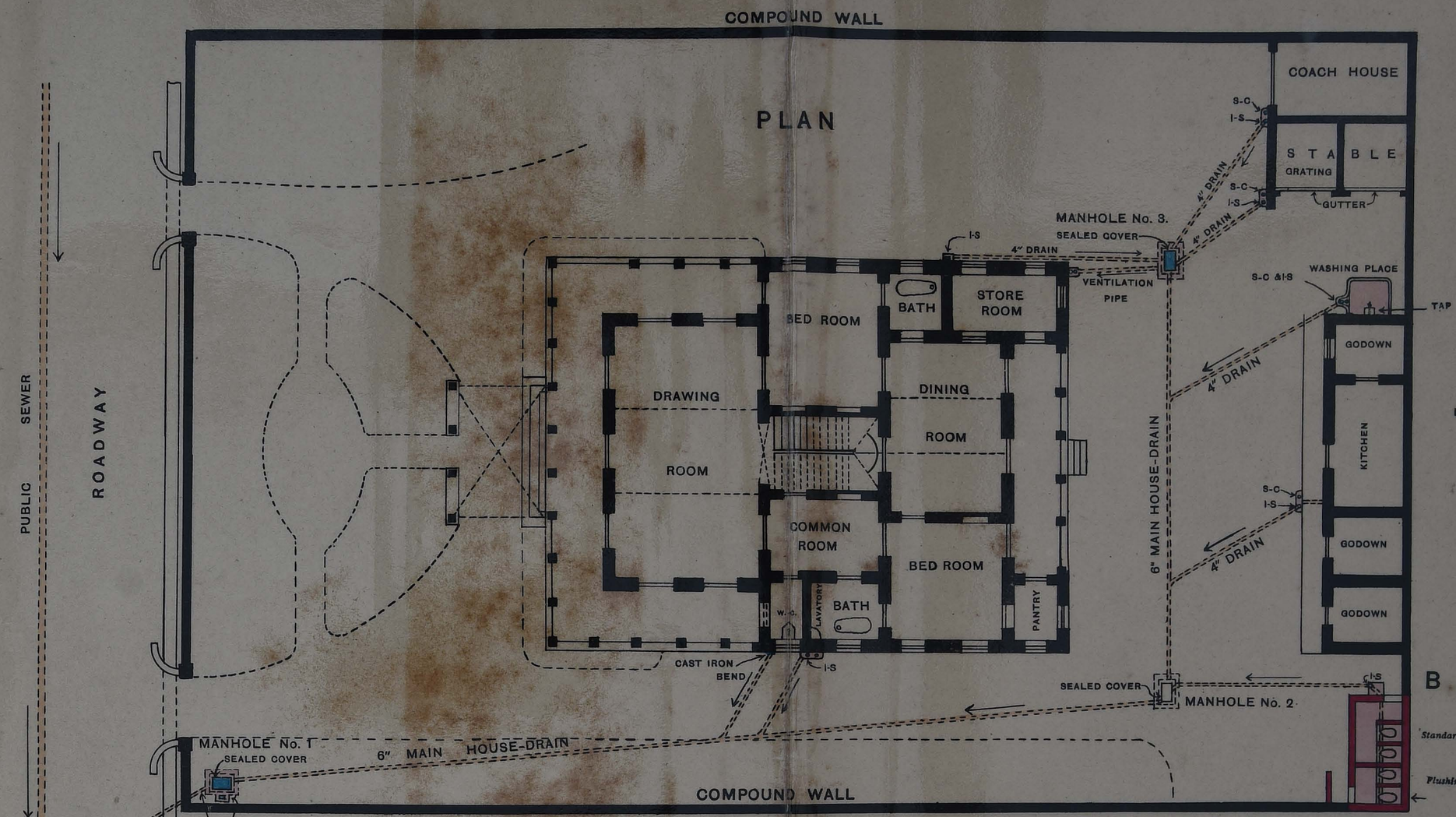
SCALE $\frac{1}{16}$ INCH = 1 FOOT

PLAN



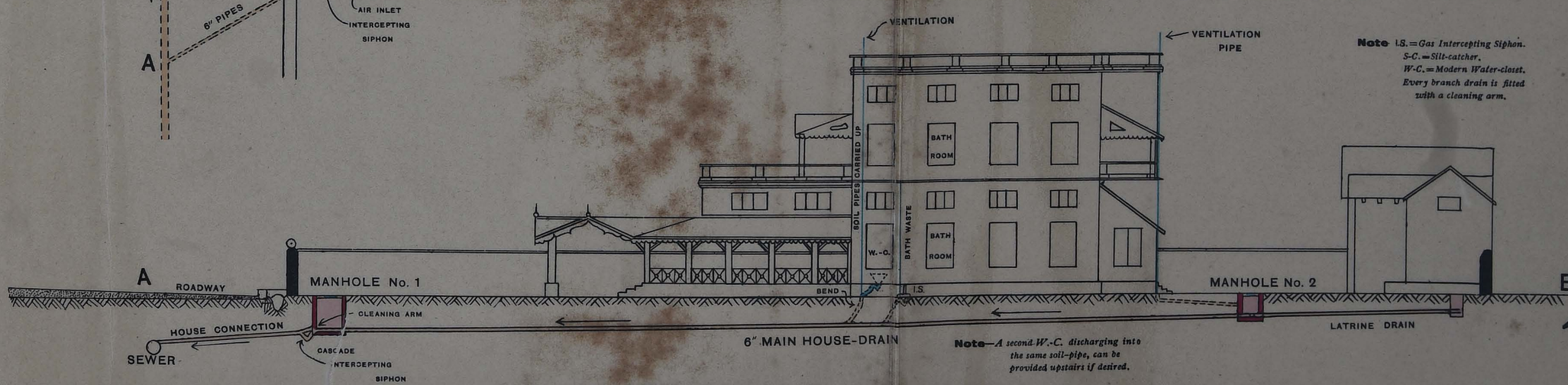
Note—*The only rain-water that will enter the drains, is that which falls upon the washing place.*

Standard type Flushing Latrine for each Seat

Flushing tank fixed over this end of latrine.

Note I.S. = *Gas Intercepting Siphon.*
S-C. = *Silt-catcher.*
W-C. = *Modern Water-closet.*
Every branch drain is fitted with a cleaning arm.

SECTIONAL ELEVATION.



Note—*A second W.-C. discharging into the same soil-pipe, can be provided upstairs if desired.*

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MARCH 1909.

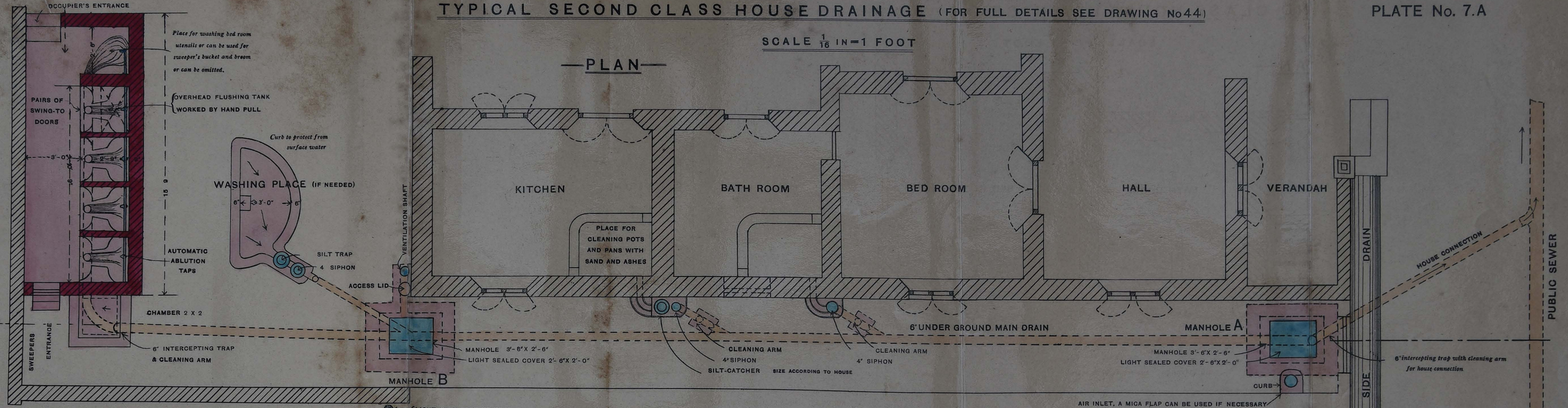
TYPICAL SECOND CLASS HOUSE DRAINAGE (FOR FULL DETAILS SEE DRAWING No 44)

PLATE No. 7.A

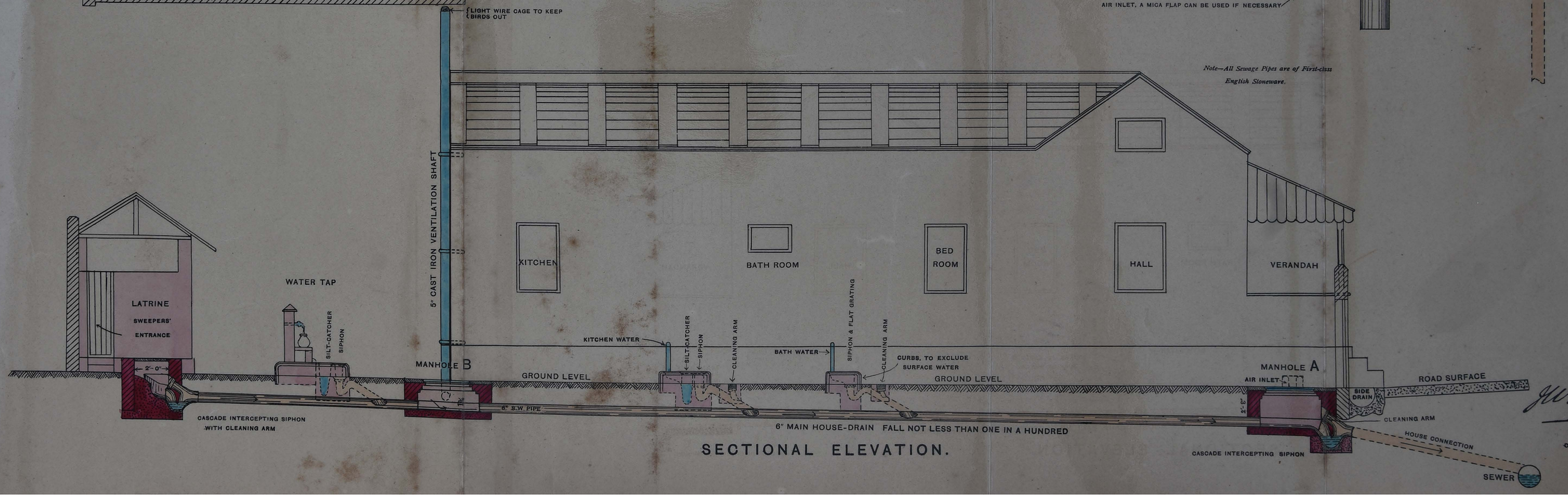
183

SCALE 1/16 IN = 1 FOOT

—PLAN—


OCCUPIER'S ENTRANCE
FLUSH-OUT LATRINE OF THE NEW DESIGN (SIZE TO BE ACCORDING TO NEEDS).
Place for washing bed room utensils or can be used for sweeper's bucket and broom or can be omitted.
PAIRS OF SWING-TO DOORS
OVERHEAD FLUSHING TANK WORKED BY HAND PULL
Curb to protect from surface water
WASHING PLACE (IF NEEDED)
AUTOMATIC ABLUTION TAPS
SILT TRAP
4 SIPHON
VENTILATION SHAFT
ACCESS LID
CHAMBER 2 X 2
SWEEPERS ENTRANCE
6" INTERCEPTING TRAP & CLEANING ARM
MANHOLE B
MANHOLE 3'-6"X 2'-6"
LIGHT SEALED COVER 2'-6"X 2'-0"
KITCHEN
BATH ROOM
BED ROOM
HALL
VERANDAH
PLACE FOR CLEANING POTS AND PANS WITH SAND AND ASHES
CLEANING ARM
4" SIPHON
SILT-CATCHER
SIZE ACCORDING TO HOUSE
6" UNDER GROUND MAIN DRAIN
MANHOLE A
MANHOLE 3'-6"X 2'-6"
LIGHT SEALED COVER 2'-6"X 2'-0"
CURB
AIR INLET, A MICA FLAP CAN BE USED IF NECESSARY
SIDE DRAIN
HOUSE CONNECTION
6" intercepting trap with cleaning arm for house connection
PUBLIC SEWER

Note—All Sewage Pipes are of First-class English Stoneware.



SECTIONAL ELEVATION.

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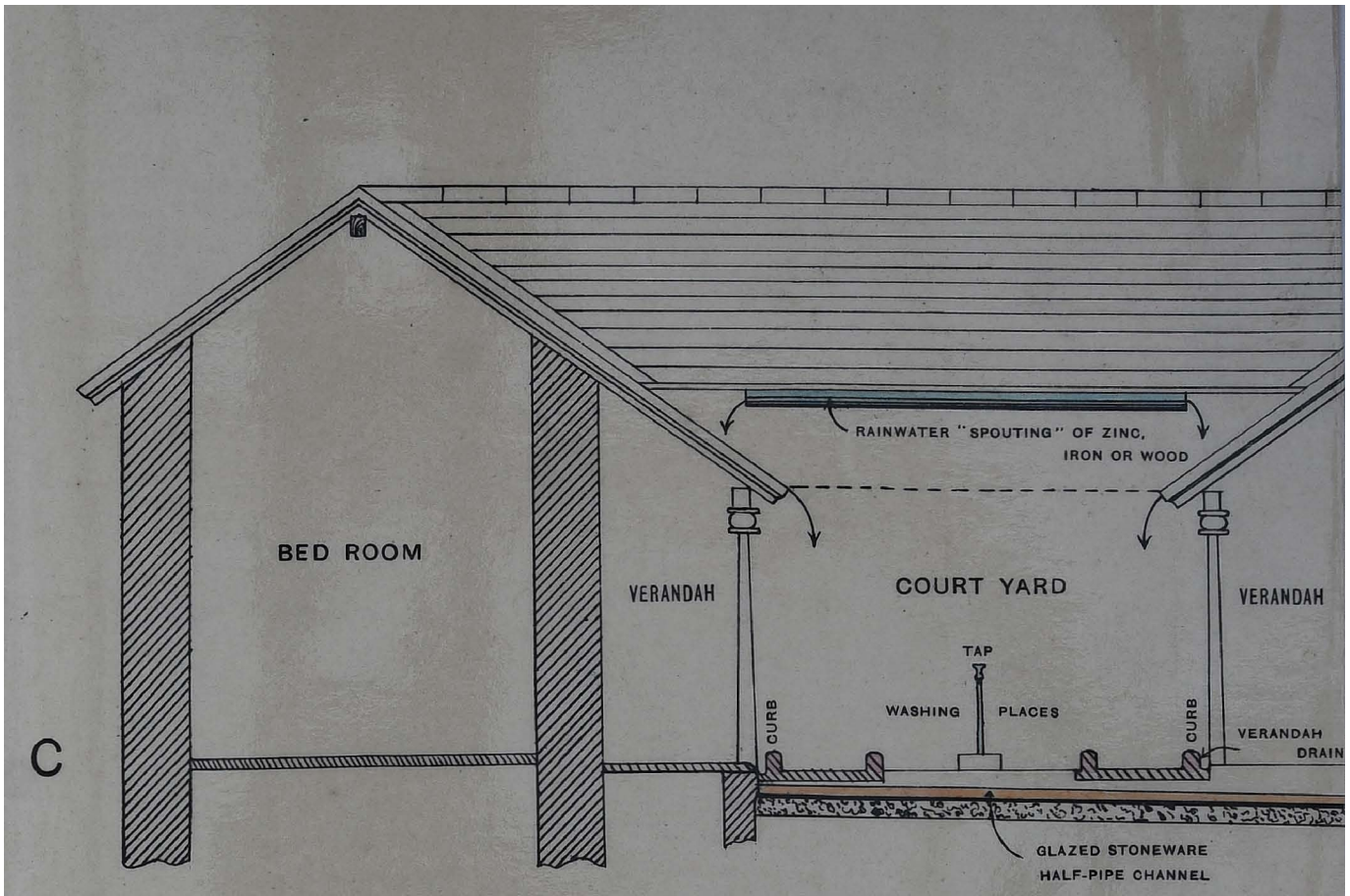
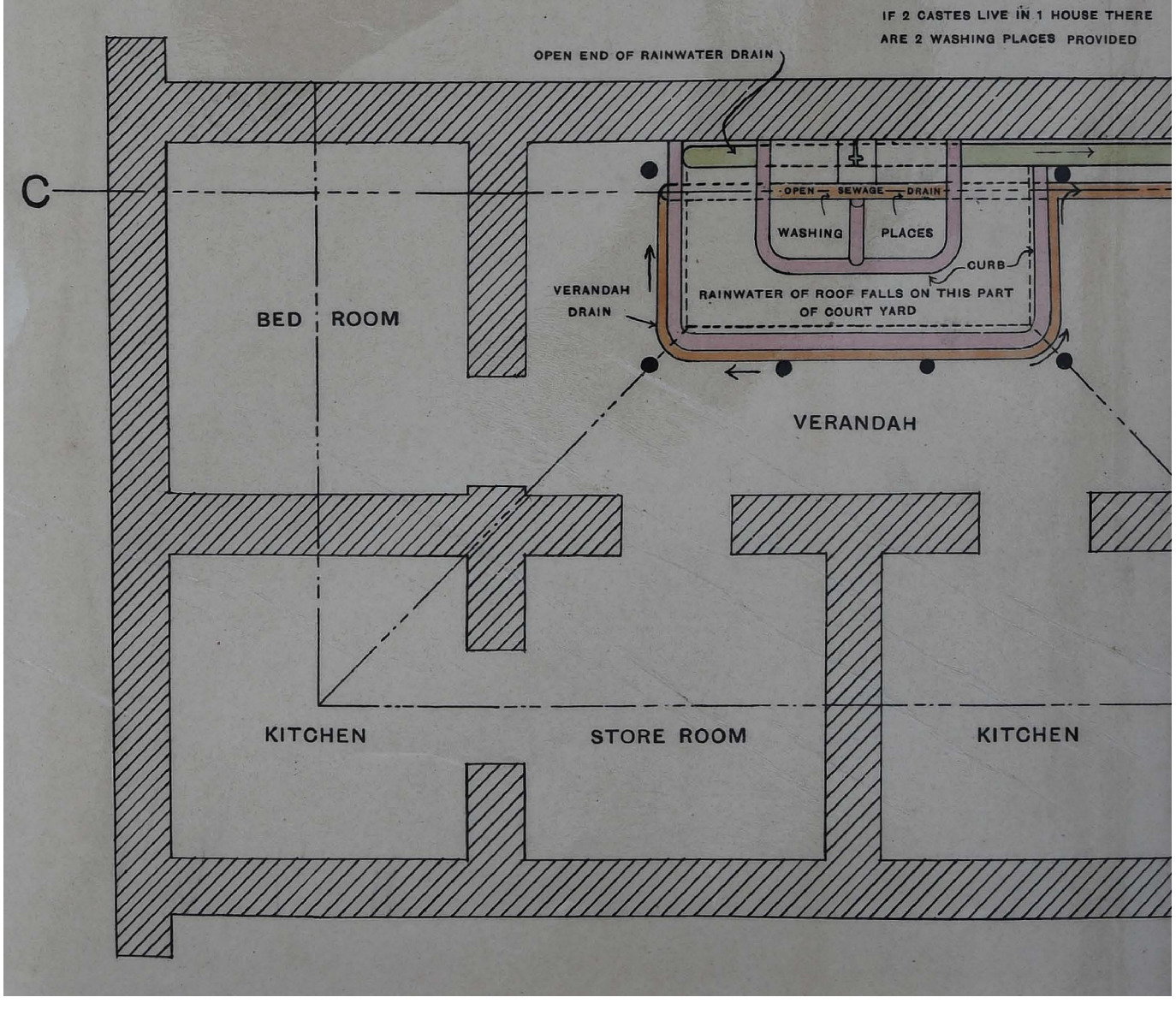
MARCH 1909.

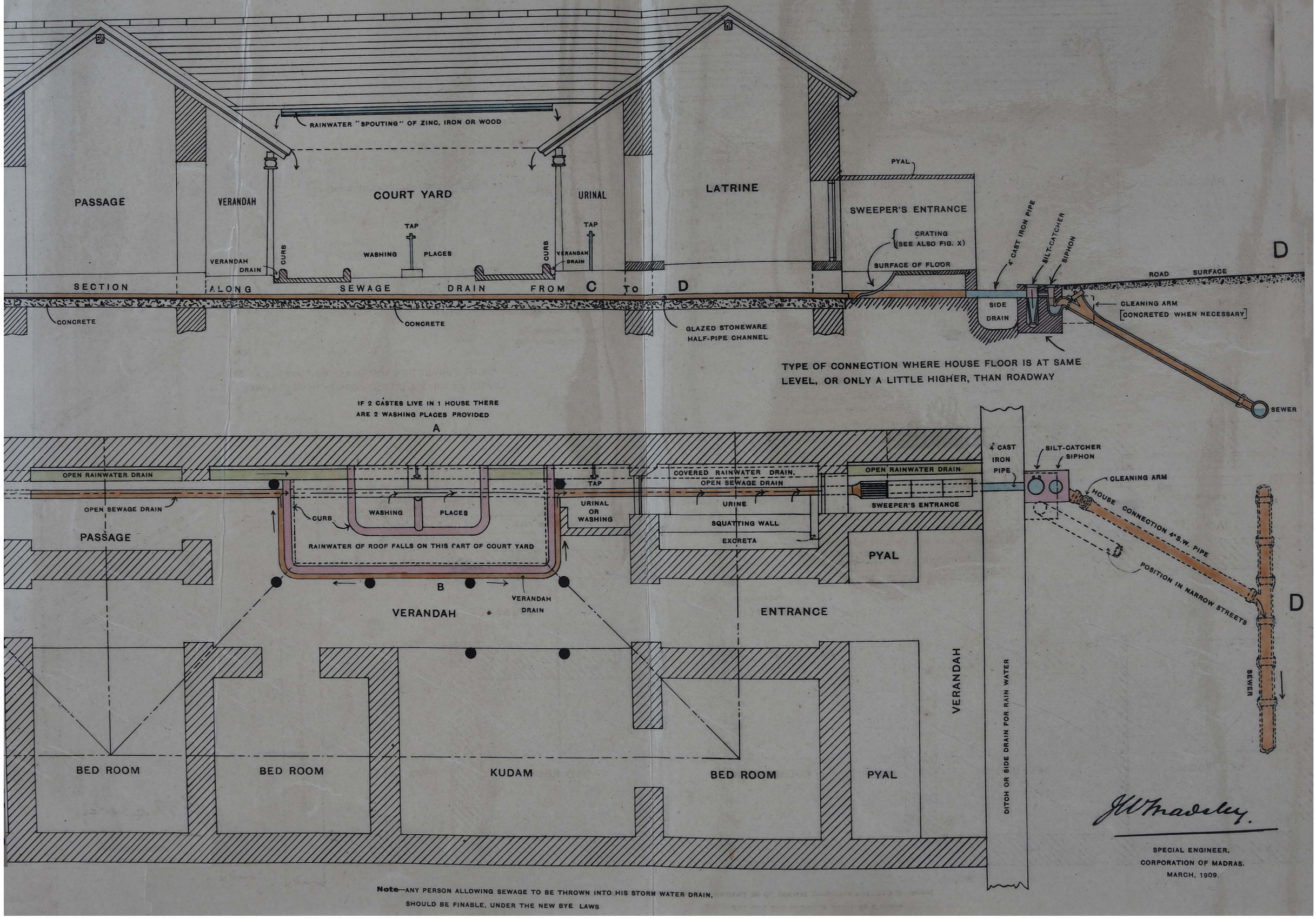

RAINWATER "SPOUTING" OF ZINC, IRON OR WOOD
BED ROOM
VERANDAH
COURT YARD
VERANDAH
TAP
WASHING PLACES
CURB
CURB
VERANDAH DRAIN
C
GLAZED STONEWARE HALF-PIPE CHANNEL


IF 2 CASTES LIVE IN 1 HOUSE THERE ARE 2 WASHING PLACES PROVIDED
OPEN END OF RAINWATER DRAIN
C
OPEN SEWAGE DRAIN
WASHING PLACES
CURB
VERANDAH DRAIN
RAINWATER OF ROOF FALLS ON THIS PART OF COURT YARD
BED ROOM
VERANDAH
KITCHEN
STORE ROOM
KITCHEN

THIRD CLASS HOUSE DRAINAGE

PLATE N

SCALE ¼ INCH=1 FOOT



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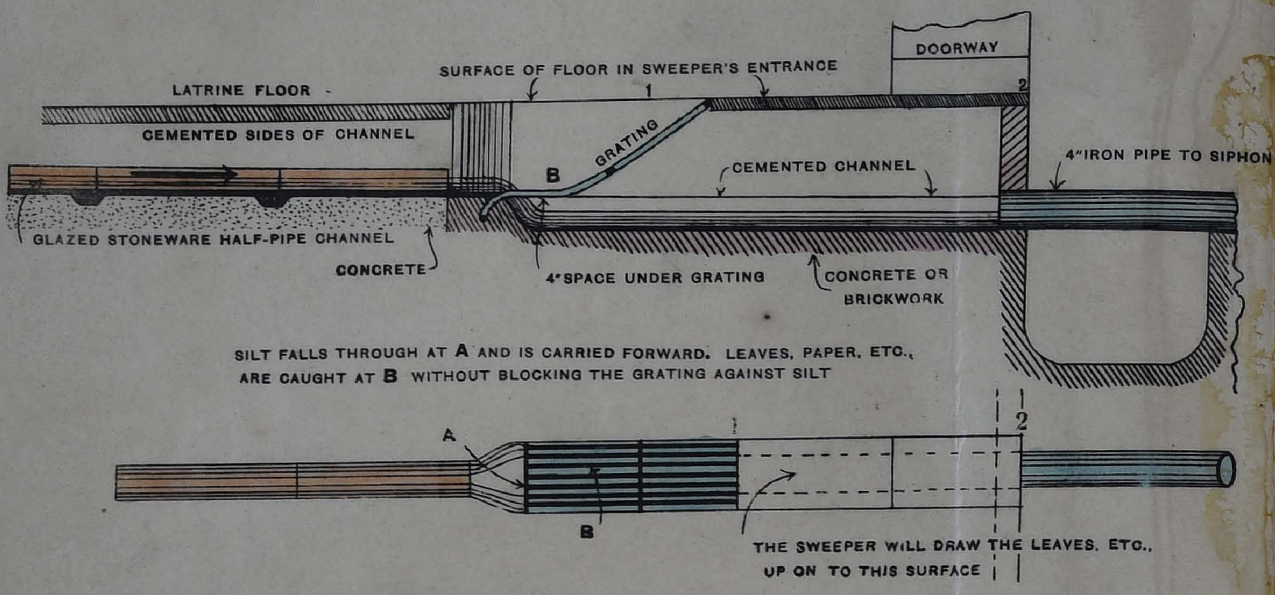
MARCH, 1909.

Note—ANY PERSON ALLOWING SEWAGE TO BE THROWN INTO HIS STORM WATER DRAIN, SHOULD BE FINABLE, UNDER THE NEW BYE LAWS

FIG. X.

IMPROVED GRATING FOR HOUSE DRAIN

WHERE POSSIBLE THE GRATING ON THE SEWAGE HOUSE DRAIN
WILL BE ARRANGED AS SHOWN IN THIS FIGURE



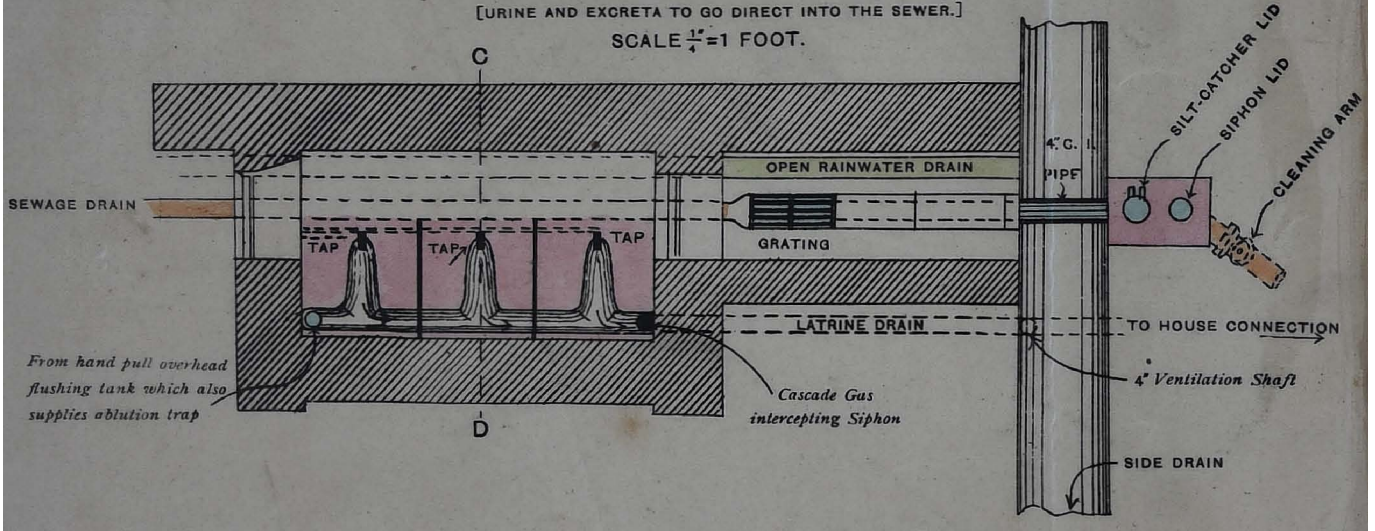
SILT FALLS THROUGH AT **A** AND IS CARRIED FORWARD. LEAVES, PAPER, ETC., ARE CAUGHT AT **B** WITHOUT BLOCKING THE GRATING AGAINST SILT

ORDINARY LATRINE

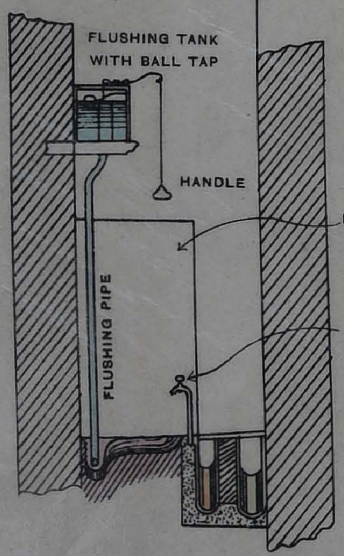
CONVERTED INTO FLUSH-OUT LATRINE

[URINE AND EXCRETA TO GO DIRECT INTO THE SEWER.]

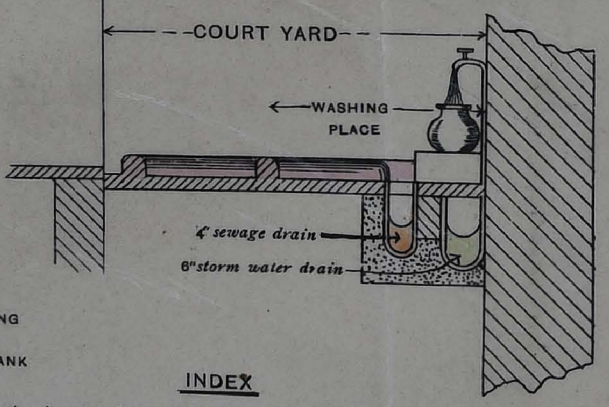
SCALE $\frac{1}{4}$"=1 FOOT.



SECTION ON C. D.



SECTION ON A. B.



INDEX

A modern water-closet can be put in if desired, and is strongly recommended where there are upstair latrines; in such cases the W.C. should be compulsory. Water-closet Pans for the squatting position can now be obtained

RAIN-WATER DRAIN COLORED GREEN
SEWAGE DRAIN COLORED SIENNA
IRON WORK COLORED BLUE
BRICK WORK AND CURBS, PINK

HOUSE CONNECTIONS — THIRD CLASS

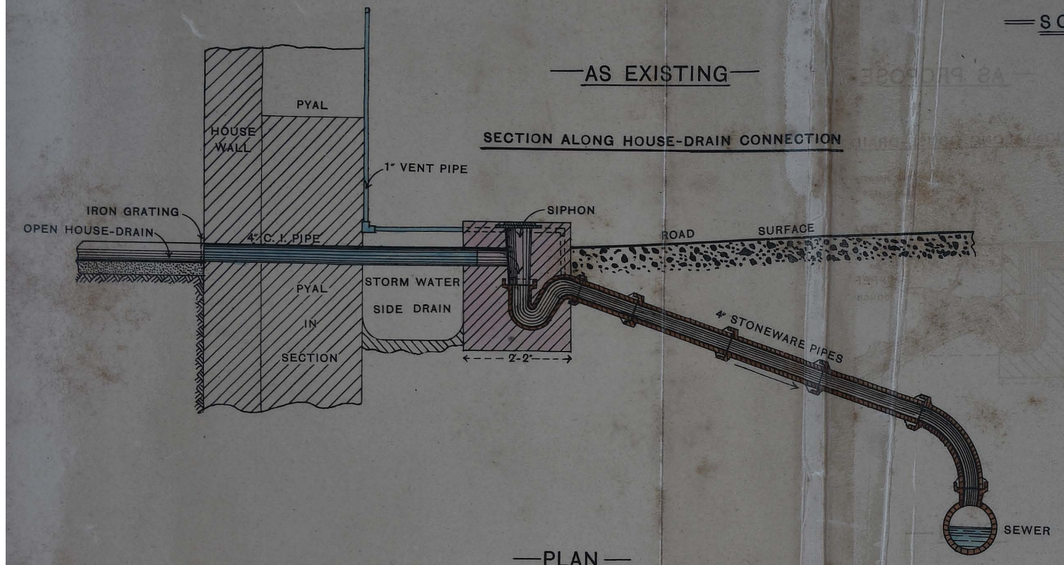
PLATE No. 8.

187

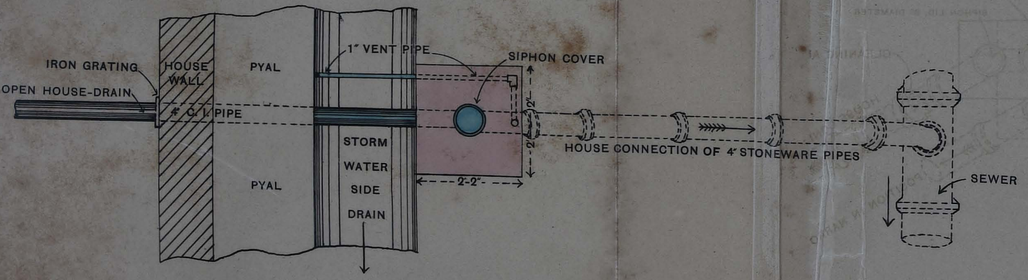
SCALE ½ INCH = 1 FOOT

AS EXISTING

SECTION ALONG HOUSE-DRAIN CONNECTION

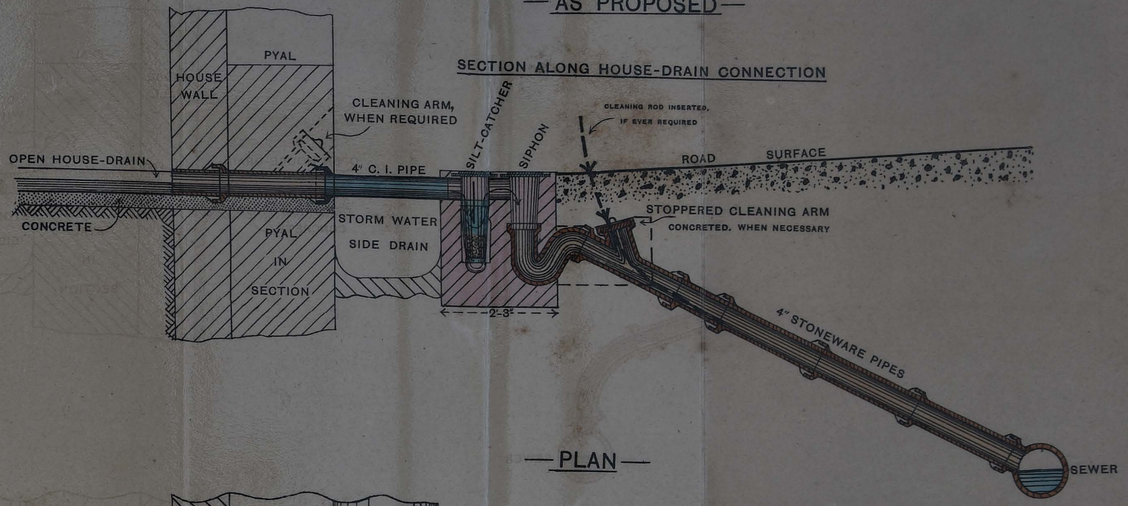


PLAN

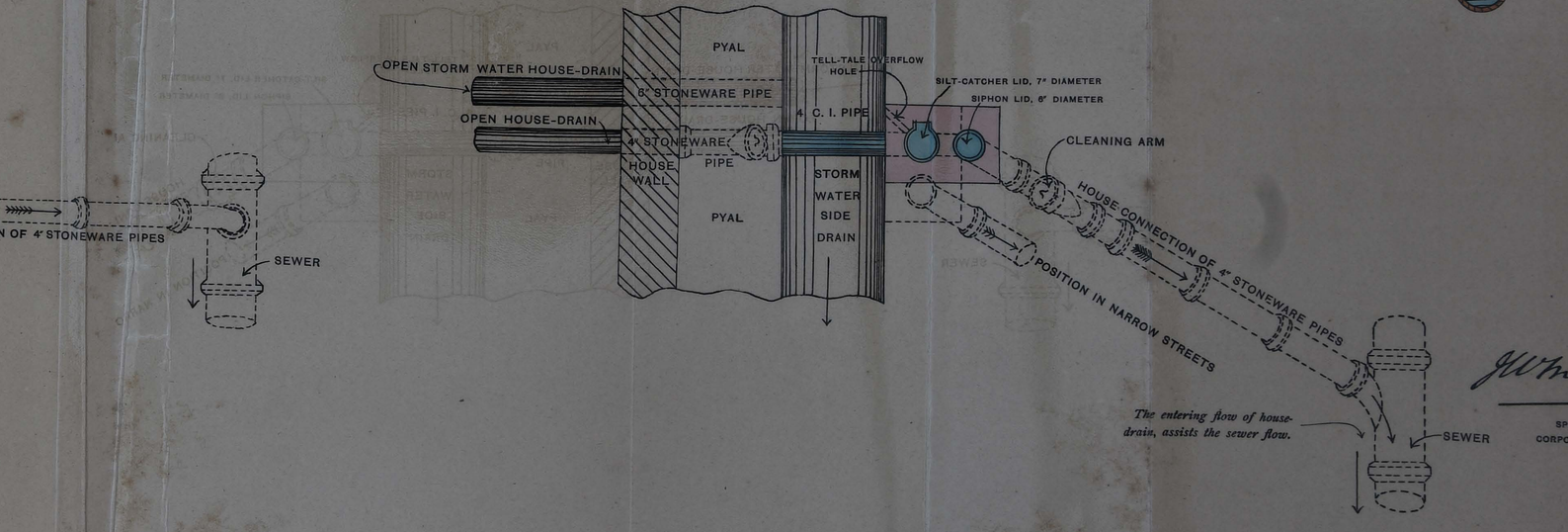


AS PROPOSED

SECTION ALONG HOUSE-DRAIN CONNECTION



PLAN



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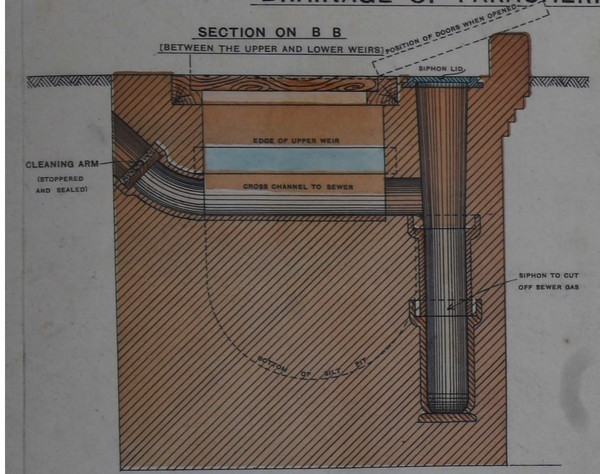
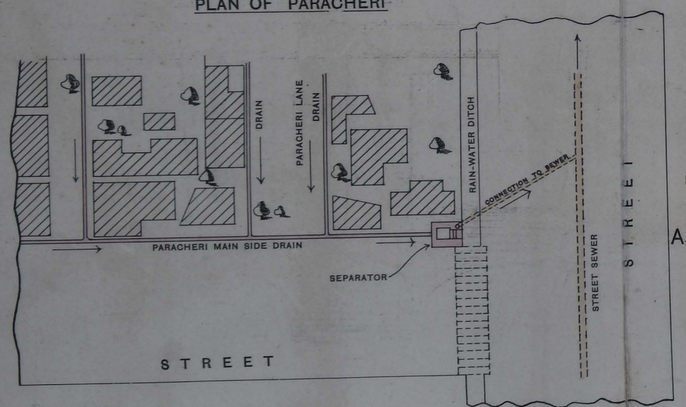
CORPORATION OF MADRAS.
MARCH, 1909.

DRAINAGE OF PARACHERIES

SECTION ON B B
(BETWEEN THE UPPER AND LOWER WEIRS)



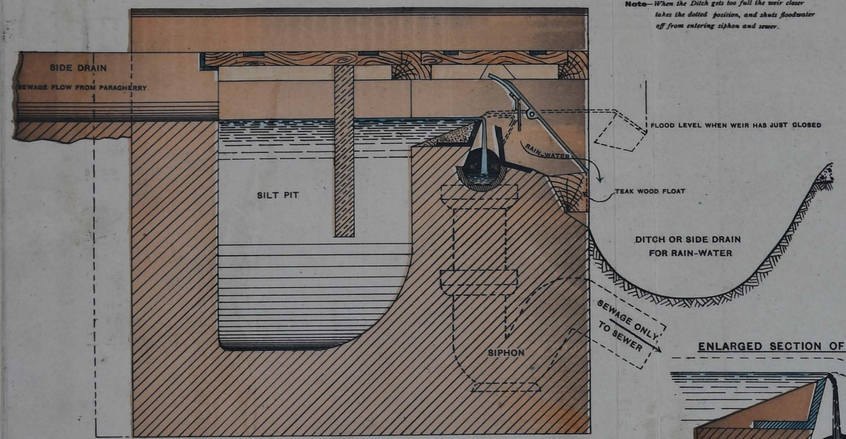
PLAN OF PARACHERI



SILT & RAIN-WATER SEPARATORS FOR SIDE-DRAIN CONNECTIONS

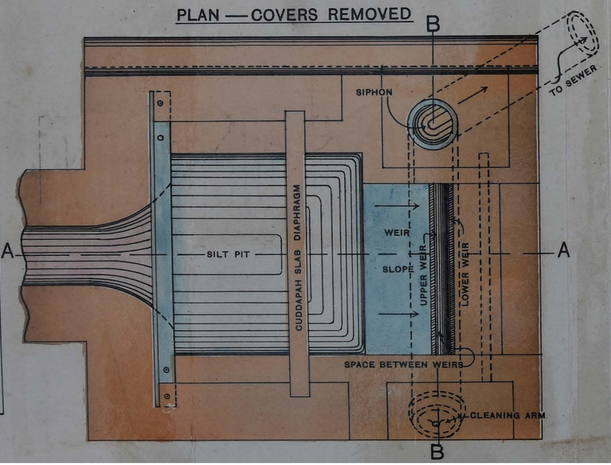
WHERE A DROP INTO A STORM-WATER DITCH IS AVAILABLE

SECTION ON A A

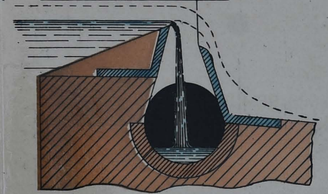


Note—*When the Ditch gets too full the weir closer takes the dotted position, and shuts floodwater off from entering siphon and sewer.*

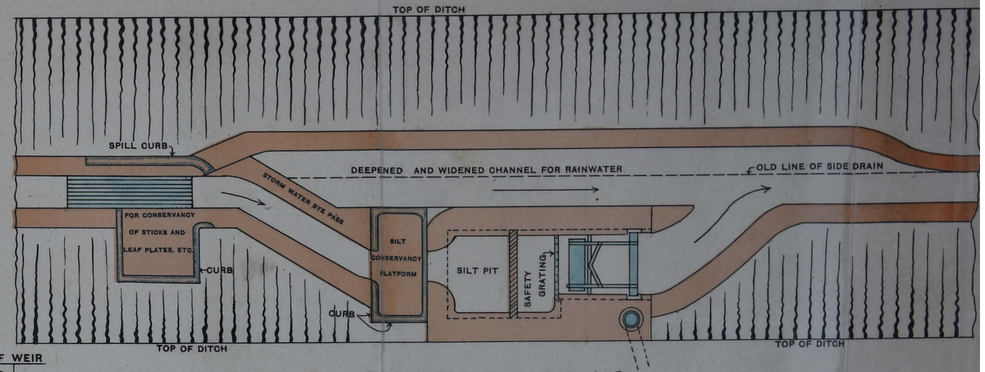
PLAN — COVERS REMOVED



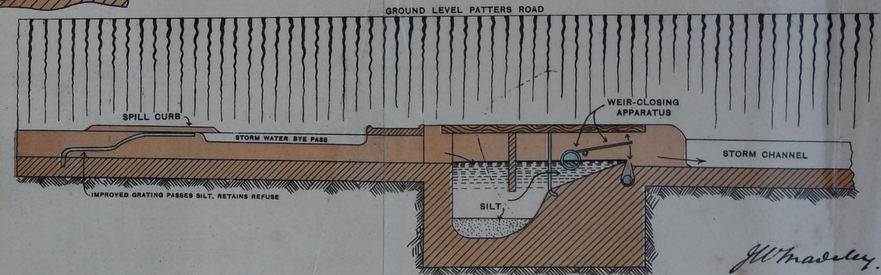
ENLARGED SECTION OF WEIR



TYPE OF SEPARATOR TO BE USED WHERE NO DROP IS AVAILABLE AS APPLIED TO PATTERS ROAD SIDE-DRAIN CONNECTIONS



PATTERS ROAD



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MARCH 1909.

PLATE No. 8.

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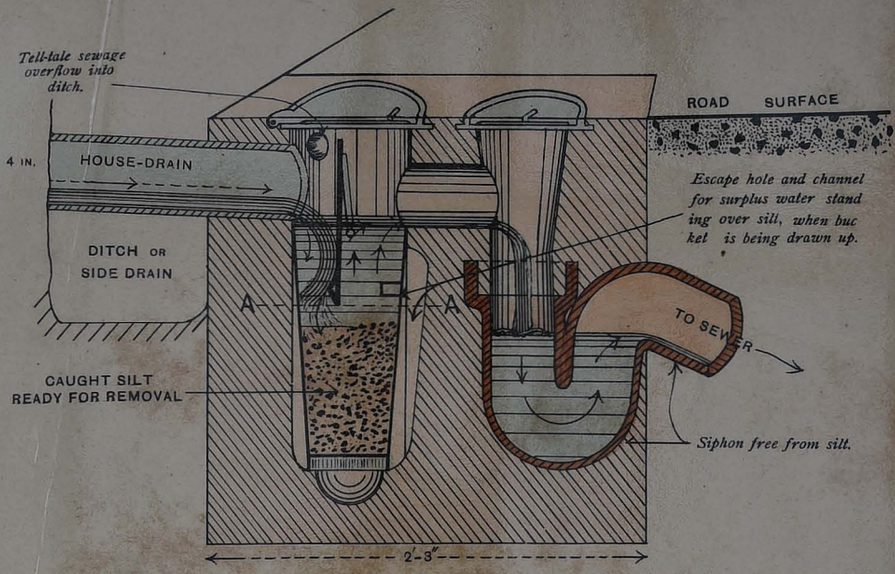
FIG. 1. — SILT-CATCHER NORMALLY AT WORK.

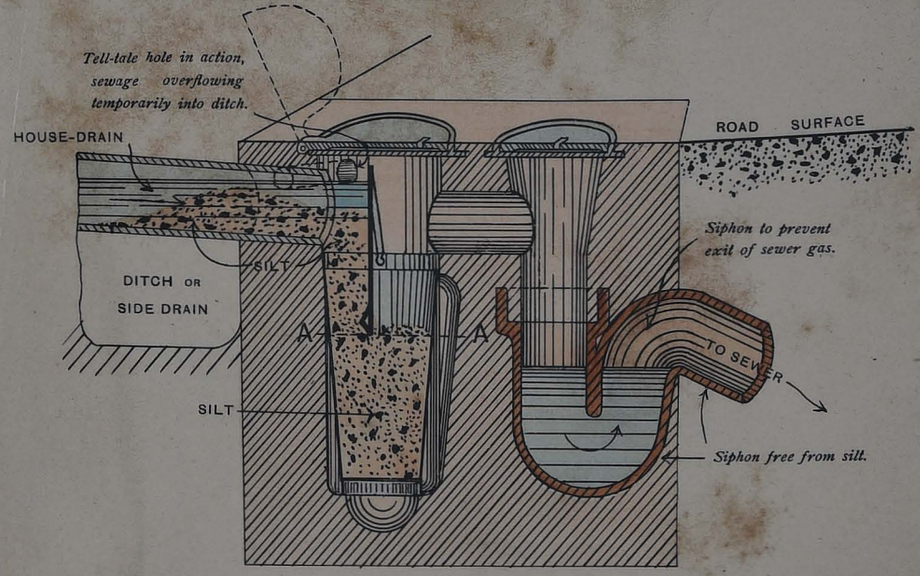


Note.—*The silt-catcher in section above (Fig. 1) is shewn to have caught its normal fill of silt, and is now ready for emptying. To empty silt bucket, the cover-lid is thrown open, the bucket is pulled up by its handle, held upside down over a bullock cart, then dropped back again into place and the cover-lid is slammed down.*

The silt-catcher prevents any silt or sand from the house-drain getting into the siphon or sewer.

If not emptied the effect is as seen in Fig. 2, but still no silt can get into either siphon or sewer.

FIG. 2.—THE SILT-CATCHER, NEGLECTED, HAS CLOSED AUTOMATICALLY ALL EXIT TO THE SEWER.



Note.—*The silt-catcher bucket should be emptied before the silt gets up to level A A, which is the bottom of the diaphragm.*

If neglected, the silt fills up only on the inlet side, as shewn, and at last causes complete stoppage at bottom end of house drain; but sewage will run out through the tell-tale hole and give warning before stoppage takes place.

The above size of silt-catcher has been found to hold about 3 days' silt coming from a house occupied by a number of families.

Even if neglected, no silt can get past the catcher, into either siphon or sewer.

FIG. 3.— SILT-CATCHER BUCKET, CONICAL FORM, 15 INS. DEEP X 7 INS. DIAMETER AT TOP

PLATE No. 9.A.

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DIAPHRAGM REMOVED

FIG. 4.

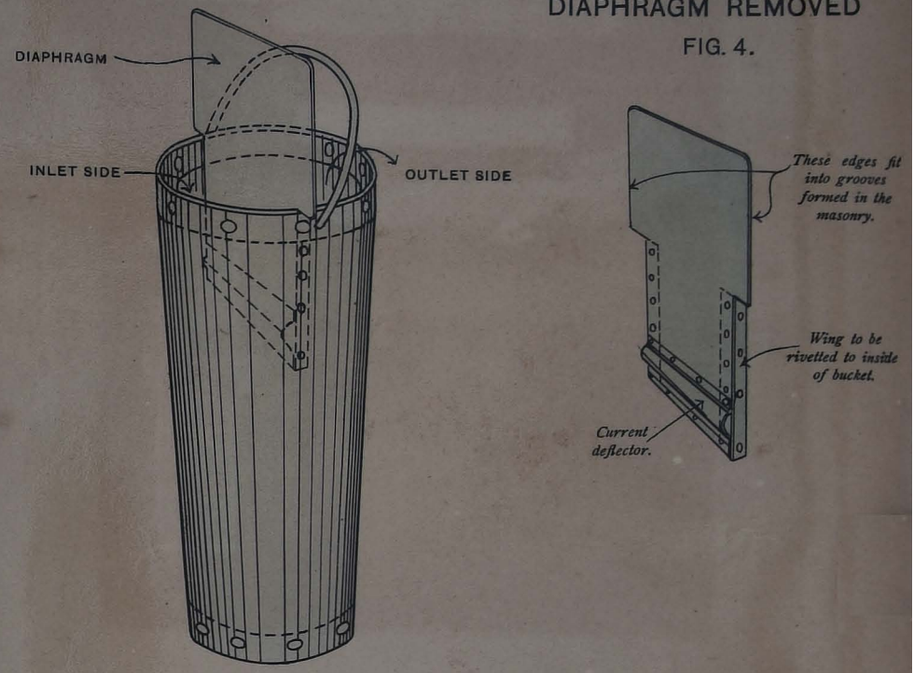
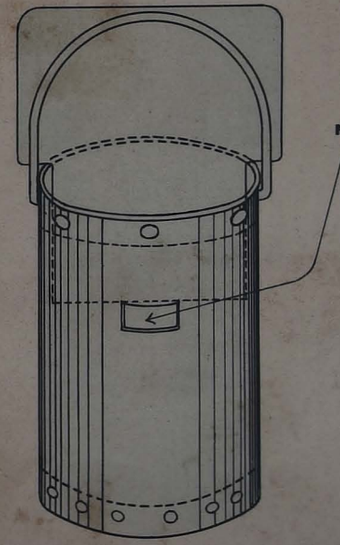

DIAPHRAGM
INLET SIDE
OUTLET SIDE
These edges fit into grooves formed in the masonry.
Wing to be rivetted to inside of bucket.
Current deflector.

FIG. 5. — SILT-CATCHER BUCKET, CYLINDRICAL FORM 10 INS DEEP X 7 INS DIAMETER



Note.—*When lifting bucket, the surplus water, standing over the silt escapes by this hole and falls back into masonry cavity. When returning bucket, the surplus water rushes back into bucket by means of this hole. All forms of silt-catcher buckets will be provided with this aperture.*

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CORPORATION OF MADRAS.
MARCH 1909.

PUMPING STATIONS A. B. C., OF SOUTH TONDIARPET, AREAS TO BE DRAINED TO THEM AND OUTLINE PROPOSALS FOR FUTURE OF NORTH TONDIARPET

SCALE 3·3 INCHES = 1 MILE

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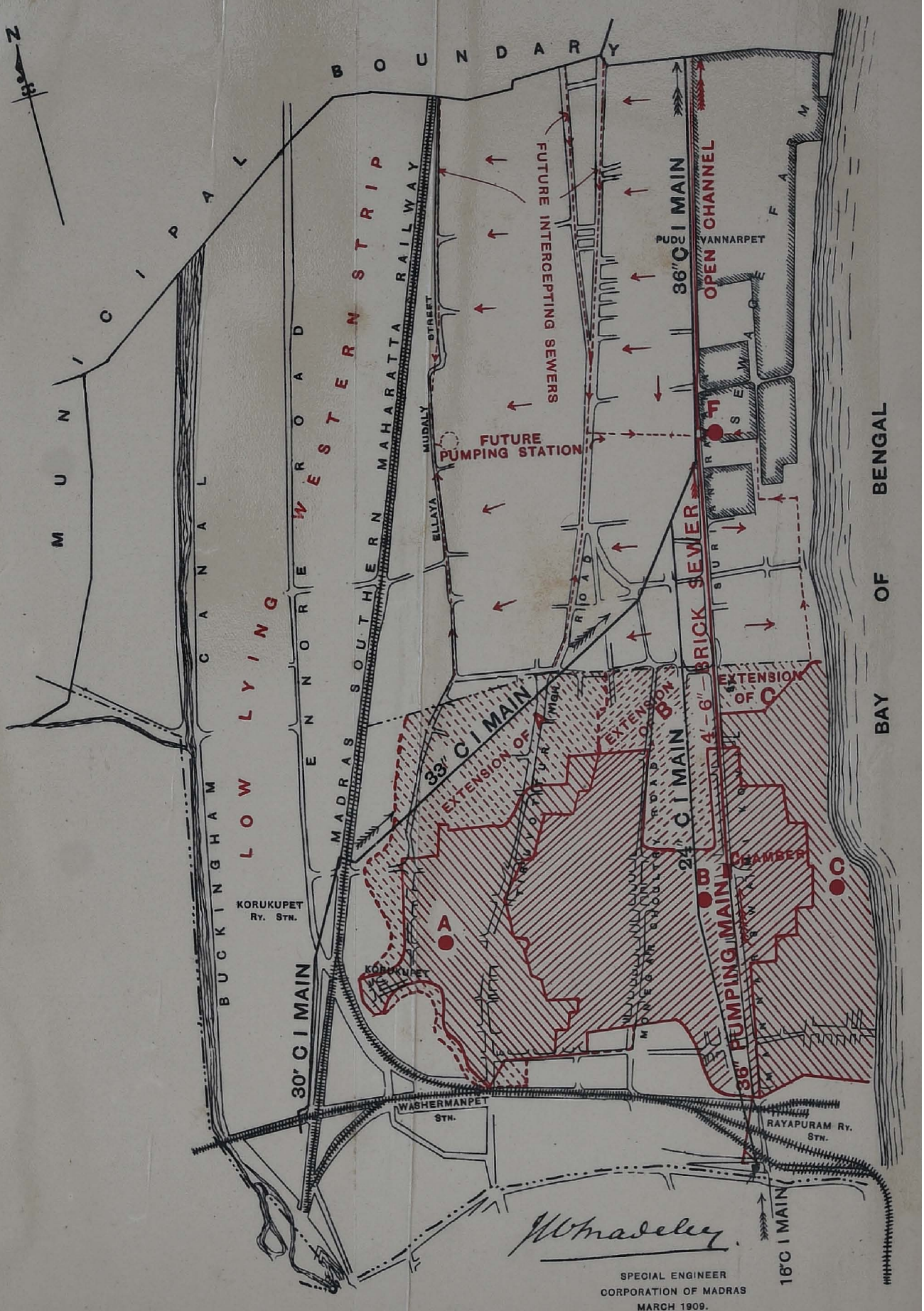

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MARCH 1909.

FIG No. 10.

PLATE No. 10.

OPEN CHANNEL AT SEWAGE FARM.

PLATE No. 11

SCALE, $\frac{1}{2}$" INCH = 1 FOOT.

TYPICAL CROSS SECTION WHERE INVERT IS BELOW GROUND LEVEL.

VELOCITY IN FT. PER SECOND	DEPTH	DISCHARGE IN GALLONS PER MINUTE	
5·40	3·50	43,300	IF SIDE WALLS ARE RAISED 6"
5·10	3·00	34,900	
4·80	2·50	26,900	
4·40	2·00	19,200	
3·80	1·50	11,900	
3·00	1·00	5,800	

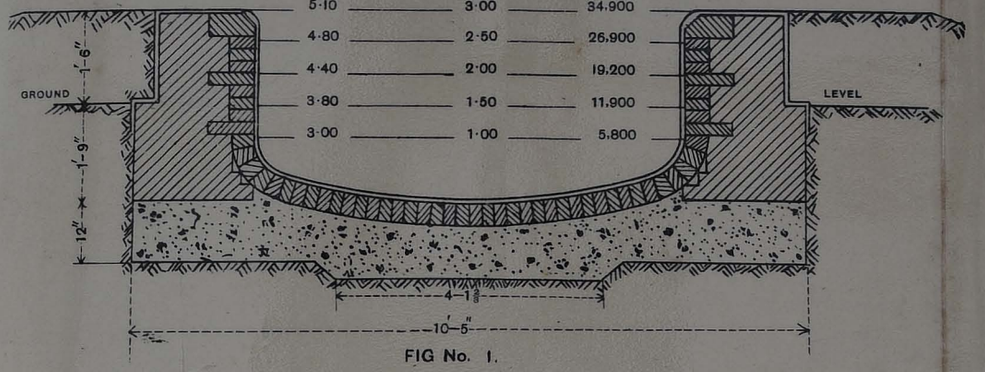


FIG No. 1.

TYPICAL CROSS SECTION WHERE INVERT IS BETWEEN G. L. & 2 FT. ABOVE G. L.

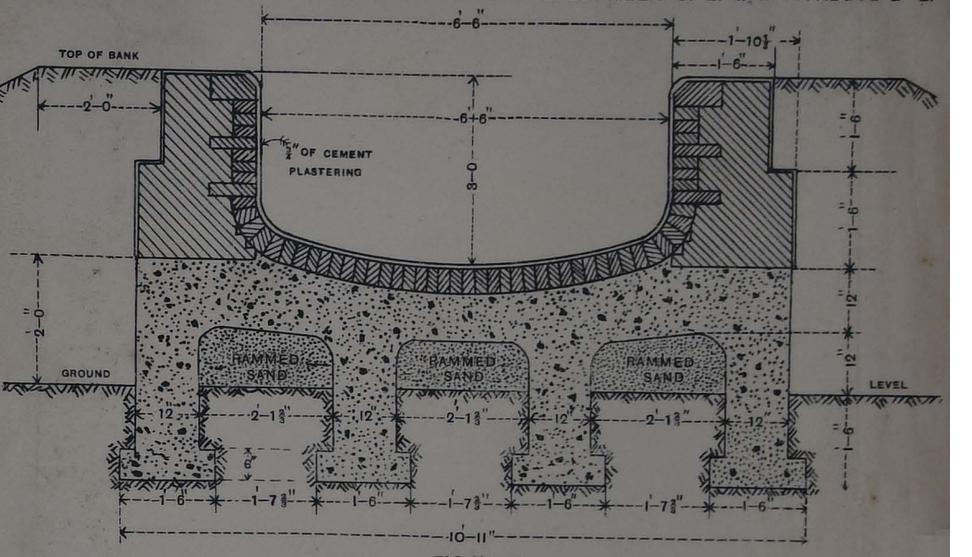


FIG No. 2.

CHANNEL ON ARCHES.

CROSS SECTION

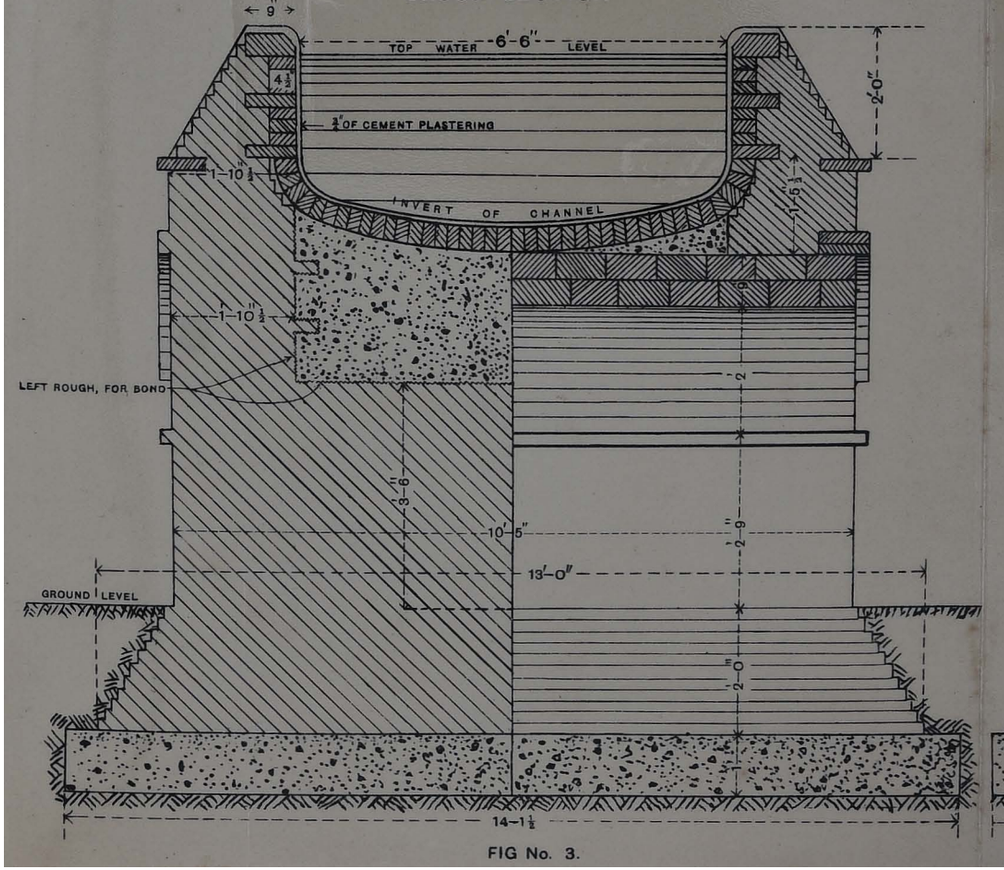
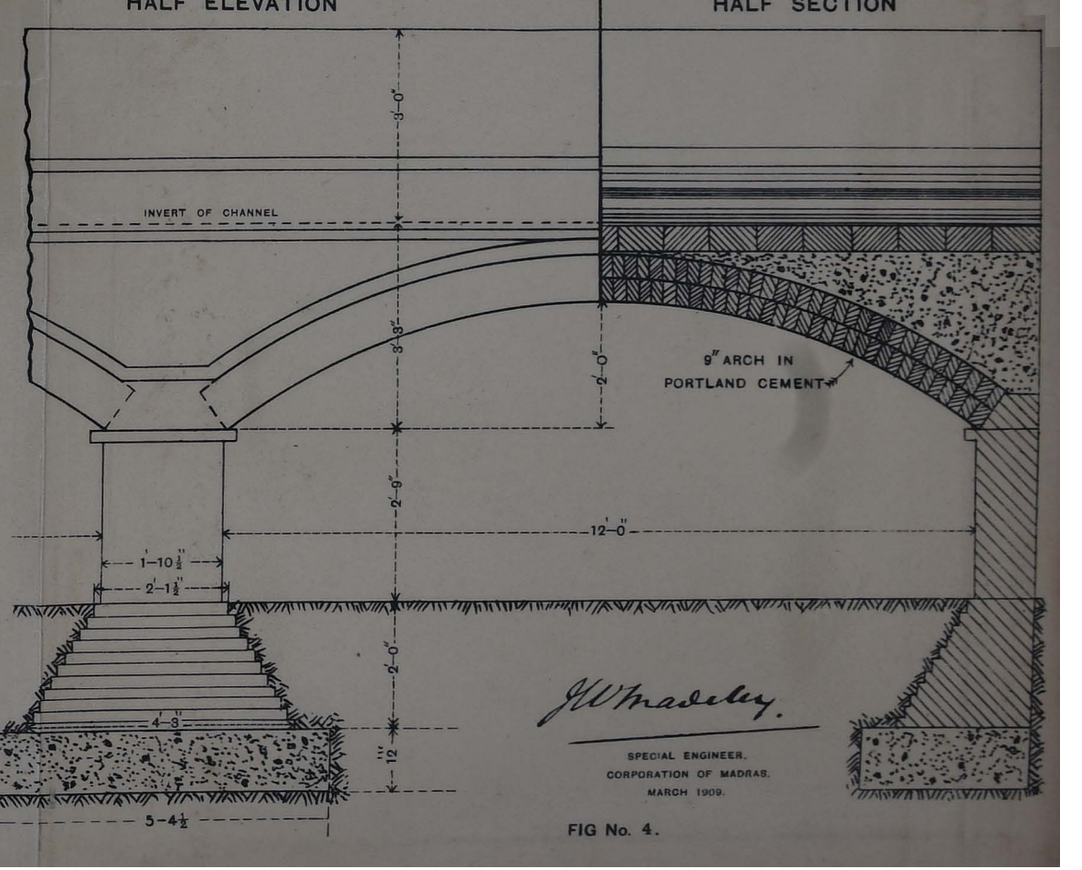


FIG No. 3.

HALF ELEVATION

HALF SECTION



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MARCH 1909.

FIG No. 4.

PLATE No. 12.

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SIDE DRAINS.

FIG. 1.

FIG. 2.

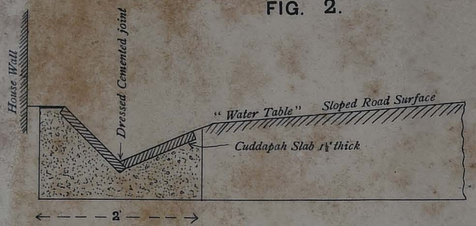


FIG. 3.

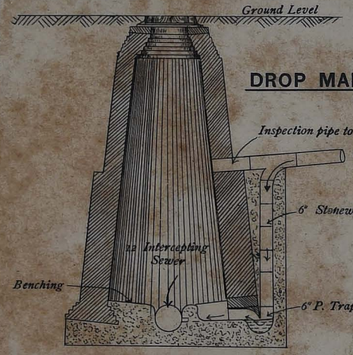


FIG. 4.

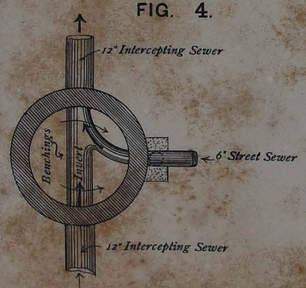
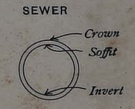


FIG. 4. A.

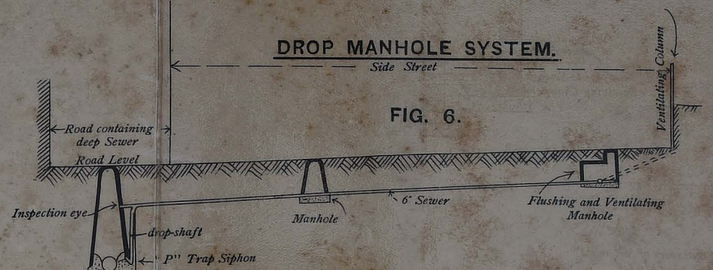


LAMPHOLES.

FIG. 5.

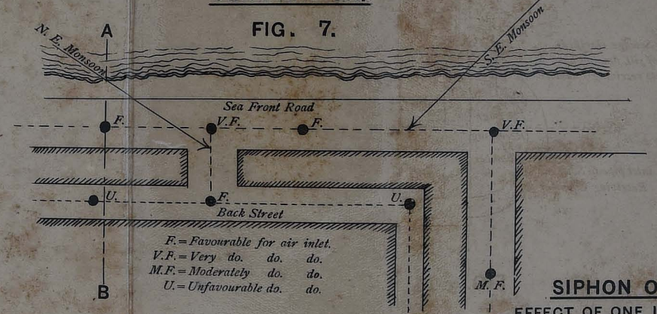
DROP MANHOLE SYSTEM.

FIG. 6.



VENTILATION.

FIG. 7.



EFFECT OF WIND ON AIR INLETS.

FIG. 8.

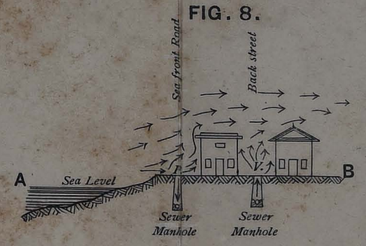
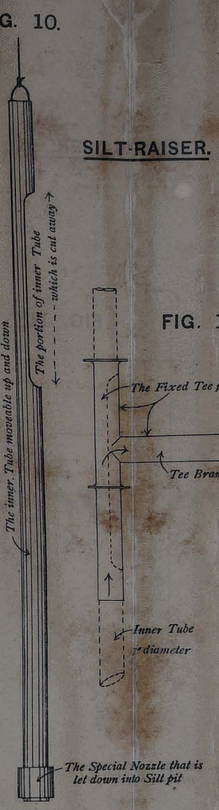


FIG. 10.


The inner Tube moveable up and down
The portion of inner Tube which is cut away
Inner Tube 1" diameter
The Special Nozzle that is let down into Silt pit

SILT-RAISER.

FIG. 11.

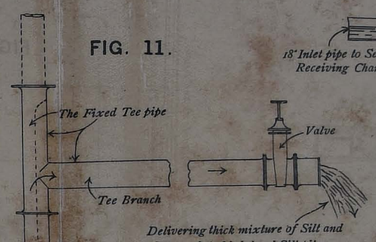


FIG. 12.

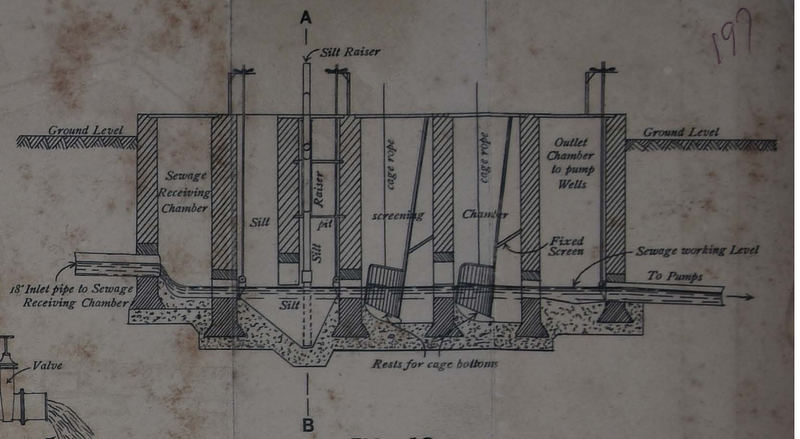


FIG. 13.

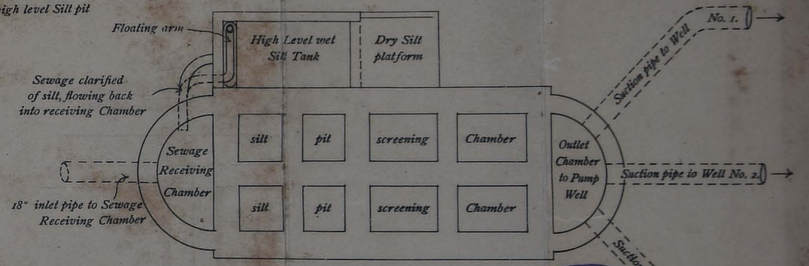
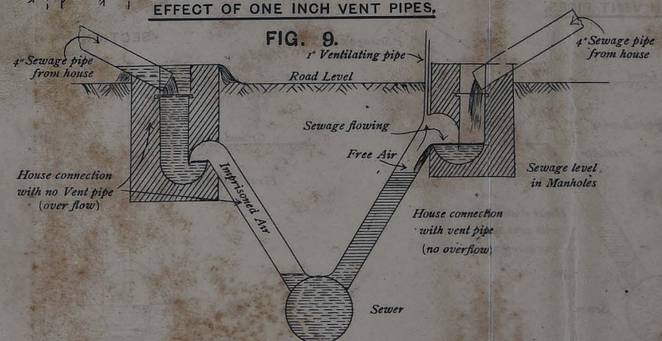


FIG. 14.

SIPHON OVERFLOW.

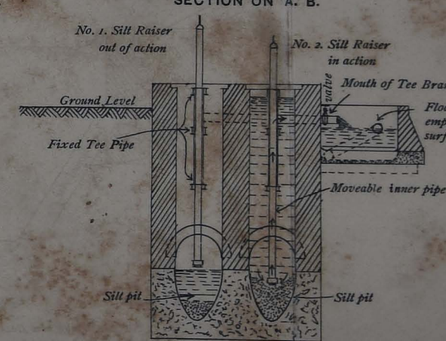
EFFECT OF ONE INCH VENT PIPES.

FIG. 9.



Sketch shewing how Backing up of Sewage may cause overflow of siphons by compressing air in House connections

SECTION ON A. B.



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